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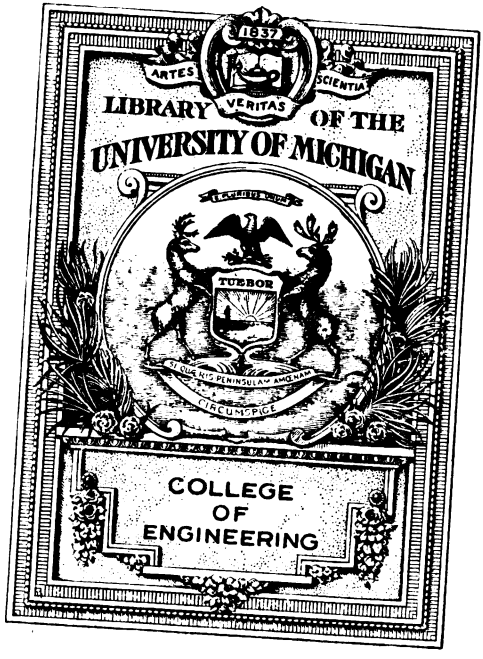
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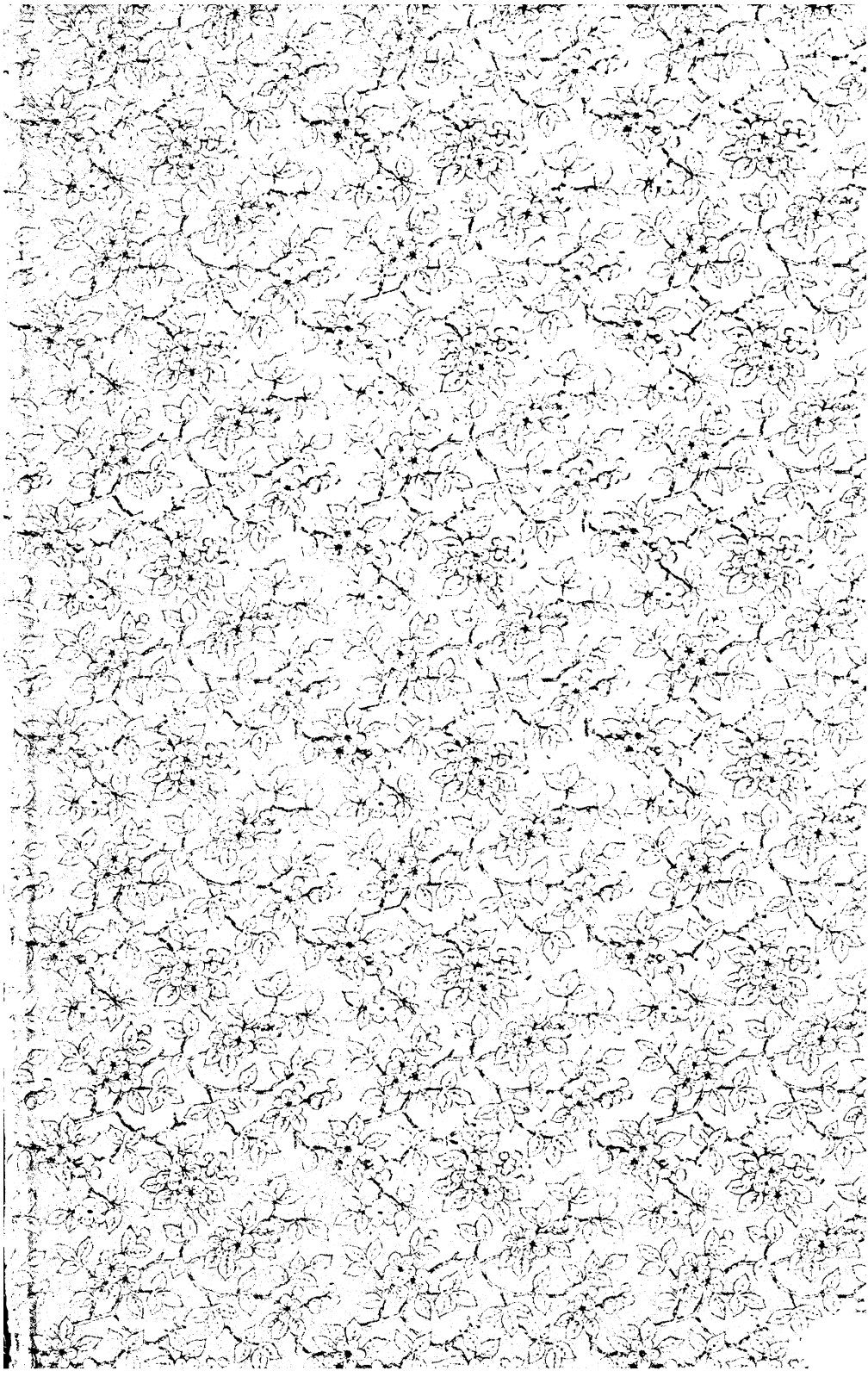

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Errata.

Page 50. Prof. Goodman writes that the formula indicated on this page is incorrect, and desires that in its place the following shall be substituted:—

Then

$$\left.\begin{array}{l}\text{Weight of steam required per I.H.P. per hour}\end{array}\right\} = \frac{13{,}750\ (1+c)\ v_2}{r\ v_0\ [p_1\ \{v_1\ (1+\log_e r) - v_c\} - p_b\ v_2]}$$

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INAUGURAL ADDRESS

BY THE PRESIDENT,

Mr. G. B. GOODFELLOW, M.I.M.E.

READ SATURDAY, 9TH JANUARY, 1892.

GENTLEMEN.

I have already had a slight opportunity of thanking you for electing me, and I now formerly thank you one and all most heartily for the honour you have conferred upon me by electing me to preside over the working of this Association for the current year. I do not wish you to listen to these words as being mere figures of speech and such as are looked upon simply as the proper things to say on such occasions, for I assure you that when I was asked to stand for election, I feared I could not successfully follow the gentlemen who have preceded me in this office during the few years I have had the pleasure of being connected with this Association, and I could not have accepted the position if I had not felt that I was in duty bound to do so after being honoured by your invitation to occupy the chief position in one of the most important Technical Associations in this country.

To my mind this Association is very quickly approaching in importance its big brother "The Institution of Mechanical Engineers," for there is no doubt that Manchester as the chief business centre of this part of the country, is possessed of more varied branches of Engineering than any other central town in the British Isles, and as our members are among the leading and most practical lights of the Manchester district, I do not think I shall be considered egotistical when saying that we constitute one of the principal Associations of the world; you can therefore now understand why I feel it so great an honour to preside over it and why I consider it an honour to be looked upon as an engineer.

I am afraid we are rather too apt to think of engineers as men who are occupied in the working of metals into some kind of mechanism, and not sufficiently as men who devote their lives and skill to the construction of any kind of useful work; we should not take this narrow view of the title, for the work of the engineer was called to the assistance of this country before the use of metals was well understood, and before tools and machinery were invented which would successfully deal with them.

In order to really establish the importance of the engineer we must go some hundreds of years back, and so find that the engineer is the former or maker of the world, but matters in this country will be sufficiently large for me to deal with to-night.

At the beginning of the 16th Century this country must have been a very uninviting place, for in different parts of it were large tracts of marsh land which were quite unfit for human beings or cattle to live upon. Among these were Romney Marsh, the Lincolnshire Fens, and the Thames valley. It is rather unpleasant to find that it was a Dutch engineer, named Vermuyden, who first showed us how to treat these lands by a system of drainage (if it had been a Frenchman I should have said it was Gauling); the work of this Dutchman seems to have stirred our forefathers into a more active state of things, for up to this time the progress of the country had been very slow, and the inhabitants were content to live easily and partake of the good things of this life when they could get them, but as these wet unhealthy districts were improved the population gradually wakened up to the new state of things; the energies and powers of application which are always stored up in good Englishmen were found, and these qualities coupled with a naturally rich country caused a commencement of a development which during two or three hundred years has been simply marvellous.

Our Island has always been noted for its ample allowance of moisture, and this was the principle element which we had to overcome in its early stages, and it was in these battles that the first skill of the Engineers was required, who turned the fierce and stubborn enemy, water, into a useful and powerful friend by leading it through channels as required, to

act as a motive power for driving machinery, supplying towns, canals, &c.

Most of us have noticed in travelling south the large tracts of land in the midland counties often under water, all this which extends through Lincolnshire, Huntingdon, Cambridge and Norfolk, or for an extent of about 65 miles long, by about 25 miles wide, which used to be a useless swamp or a series of fens, and was known as the Great Level of the Fens. It is peculiar to note that this low lying district is about opposite to a very similar one in Holland. This vast fen area of about 1,600 to 1,700 square miles was a kind of inland sea in winter and a pestilential pond in summer, and evidences in the way of ships' timbers have been found in the river at Lincoln, showing that some time there has been sufficient water to float ships up the river. About the time that a great deal of this fen work was proceeding the River Thames was gradually being controlled, but in consequence of troubles between Church and State the works and embankments were so much neglected that the water broke through in several places, and it was at or about this time that James I. took such an interest in the works that matters were soon put into shape, and drainage schemes were carried out in many parts of the Country from the Thames in the South, North Yorkshire, Devonshire on the West, and Lincolnshire on the East.

But even in these remote times we find that the engineer suffered from the objections of the people to anything new quite as much as at the present day, for during the time that Cromwell led the Country disturbances were commenced which ended in riots, and a general demolition of the works and embankments which had been constructed with so much expense and perseverance, so that the country was again allowed to be drowned. It was not until about the middle of the 17th century that the Duke of Bedford had Parliamentary powers granted which allowed him to proceed with the restoration of the work, but it was then found that there was such a strong feeling amongst the general population against the undertaking that it was impossible to obtain labour to carry out the work; this difficulty was partially overcome by setting to work about 1,000 of the Scotch prisoners taken at Dunbar, and in course of three or four years matters

were pretty well put straight again. These reclamations proceeded under varying difficulties for the next 100 years, windmills were erected to pump the water from the lower levels and the work was gradually completed in such a way and under such unbounded difficulties that I think we may safely call these works the commencement of English Engineering.

Leaving the dirty water and getting into what should have been clean, we find that in the latter part of the 16th century London was beginning to cry out about its water supply, but before this in the year 1478, one William Campion, of Fleet Street, had tapped the conduit where it passed his door, "thereby occasioning a lack of water to the inhabitants," for which he was taken before the Mayor and punished in the following way. He was set upon a horse and a vessel with a perforated bottom fixed upon his head, the vessel was repeatedly filled with water which dripped over him while he was taken round, and a proclamation of his offence read over at the following places: Leadenhall, the pillory in Cornhill, in the Chepe, Ludgate Bridge, Fleet Street, Temple Bar, and at St. Dunstan's Church, and afterwards locked up during the Mayor's pleasure; thus the early scarcity of water in London is formally recorded. At this time the water was mostly carried from the Thames to the city by carriers, who were an unruly lot of men. The river must have undergone considerable changes since then, which changes are also due to the work of the engineer.

In 1582 Peter Morice obtained powers to pump the Thames water into the city, which he did by means of a pump worked by a wheel accelerated by means of the rising and falling tides, the wheel being fixed at the first arch of London bridge, and the water conveyed in leaden pipes with such force that it could be lifted over the top of St. Magnuses' steeple, "to the astonishment of the Mayor and Aldermen." Now, soon after this more serious difficulties commenced, the town grew very rapidly, the population increased, and the river which was used as the main sewer and water supply began to get unfit for domestic use, and the problem soon became such that not even the Londoners could at once solve. Powers were granted to William Inglebert, in 1606, to convey the water from the springs in the northern part of the city "in trenches

of brick," but this scheme was not carried out, and for some years nothing was done to prevent the Londoners enjoying Thames water. While all these difficulties were being experienced in London, Plymouth was undergoing similar sufferings, and our then distinguished Admiral Sir Francis Drake obtained an Act of Parliament in 1587, to supply water to the inhabitants of Plymouth. This work was nothing more than a good trench cut along the hill sides and across one small aqueduct, but some ingenuity had to be exercised in getting the requisite inclination, for although the distance the water was conveyed was only about 7 miles in a straight line, the trench itself measured upwards of 24 miles. Although there might not be a large amount of engineering skill displayed in carrying out this work, Sir Francis Drake showed a great amount of pluck and confidence, for he provided all the money for carrying out the work, except £200 which was found by the Corporation of Plymouth, and completed his work in 1591.

During all this time London was still enjoying the Thames liquid, and it was not until early in the 17th Century that Hugh Middleton, who was not an engineer but a goldsmith, came forward to help the Londoners from being poisoned. At this time the population of London only numbered about 150,000, in fact, consisted of little more than what is now called the city; there were not any buildings east of Aldgate, north of Cripplegate, or west of Smithfield, there were only a few thatched cottages in the Strand the river coming almost up to them, where the boats were moored at the water's edge; Holborn, Clerkenwell, Finsbury, St. Pancras, St. Martins, St. Giles, &c., were little country spots dotted round the city. Here again came forward the usual feeling of opposition to anything new, and farmers and landowners with many more opposed the making of the conduit from near Ware in Hertfordshire to London, but this man who may now be styled an engineer, perseveringly fought his way along until he so nearly completed his scheme, that he obtained the assistance of King James I, who entered into an agreement with him which enabled him to complete his work of about 38 miles of waterway by Michaelmas 1613. The works were called the New River, and the water was brought into London. Amidst great rejoicings this work was gradually matured.

The water was conveyed to the houses and different parts of the City chiefly in wooden pipes. During this time Sir Hugh Middleton (for the King had knighted him) was gradually disposing of parts of his interest in the undertaking, and the Shareholders of the New River Company were incorporated under letters patent on the 21st June, 1619. As near as I can find the value of the shares at this time was £250 each, but as the next 17 years only brought in about £18 per share in dividends it was looked upon as a very poor undertaking. I forgot to say that when James I. made his arrangements with Middleton he stipulated to hold half the property which seems to have descended to Charles I., but as the profits were extremely small and the property had to be maintained it became necessary to call up additional capital. This seemed to be inconvenient to Charles, who I have no doubt required all his spare cash, for at this time he granted his half of the property to the Company in consideration of a rent or return of £500 per annum, which I believe is still paid by the New River Company to the Exchequer. Notwithstanding this unfortunate commencement of the Company prosperity set in at this time, and by the end of the 17th century the dividend was about £200 per share, and a century later about £500; it might be somewhat dangerous to speculate as to what the present dividend is, but the shares are so valuable that they are occasionally dealt in by fractions.

Sir Hugh was not yet tired of his work for he was soon busy again in reclaiming land, coal mining as well as silver and lead mining. He was at length made into a Baronet, and died in 1631 at the age of 76 years.

Leaving water for a while we will get on land and have a look at the roads and the modes of travelling. The roads, if such they could be called, up to the sixteenth century were mostly made by the people and horses treading them down. In some cases they were hollowed below the rest of the ground, so that in the winter or bad weather they were almost impassable for either man or beast (vehicles or carriages were not yet heard of); even the streets in the city of London were often too bad to get along unless on horseback. The Romans seem to have had a better way of making their roads, but they were not copied by the early English. Up to about 1550 all travelling seems to

have been done on horseback, except when mules and donkeys were used, and where the people were too poor and had to walk, but these latter seldom went far from home, and many of us must know of instances where country people never went far out of their own valleys until railways came to put most things on a level. In the times I was speaking of, kings and queens had to ride, judges rode their circuit in jack-boots, gentlemen and robbers rode, and occasionally there was a most unpleasant mixture on the road; in fact, the road was a most dangerous place in many ways. Queen Elizabeth was often on horseback for long distances at a time, but when she entered the city she rode on a pillion at the back of her Lord Chancellor. After a time she was provided with a coach, which from the description of it I should imagine was more like a farm lurry than a carriage. These lumbering carriages were first of all only used on state occasions, for in fact they were so uncomfortable and slow, the roads so wretchedly bad, that I should say it was more a matter of pride than comfort that induced any one ever to ride in them. In 1583 Sir Henry Sidney entered Shrewsbury in his coach, with a trumpeter blowing, and we are told it was a sight very beautiful to behold. After this coaches became more common, but in many cases great delays occurred by reason of accident on the road, and often juries and counsel were kept waiting for judges on circuit, and they often imposed fines upon districts where their thumpings and bumpings made them aware that the roads were worse than usual. In those days a coach could travel 10 to 15 miles per day, provided there were no accidents. What would some of us think if we had to go back to these times, seeing that we now grumble if being five or ten minutes beyond our allotted time in going about 200 miles in about five hours?

The stage-coach was now beginning to make rapid progress towards more general favour, but there was nothing of the kind travelling to Lancashire, Yorkshire or Cheshire, until the latter end of the 17th century; afterwards there was one from Leeds and York which performed the journey of 24 miles in eight hours, and it is said of the drivers of the coaches that they were "seldom sober, never civil and always late." In 1663, one Edward Parker, who had ridden from Preston to London, wrote

to his father and said, "I got to London on Saturday last, but my journey was in no ways pleasant, being forced to ride in the boote all the way. This travel hath so indisposed me that I am resolved never to ride again in ye coach."

Coaches, like all other improvements, no matter how small, met with many opponents, and if you will excuse me occupying your time with this small talk, I will quote you some in order that you may see how near they compare with the objections raised to our more modern horse and conveyance, the locomotive and the railway train. In 1673 stage-coaches were objected to as "one of the greatest evils which had yet happened to the kingdom, were mischievous to the public, destructive to trade and prejudicial to lands. The use of the coach would destroy the breed of horses, interfered with the training of watermen and seamen, and interfered with the public resources. Those who were accustomed to travel by coach become weary and listless, and were unwilling to get on horseback; not able to endure frost, snow or rain, or to lodge in the fields—whatever that may mean—that people rode in coaches to keep themselves clean and dry, save their clothing, and so became idle; all this was ruinous to trade, as most gentlemen before they rode in coaches used to ride with swords, belts, pistols, portmanteaus and hat cases, but in these coaches there was no occasion for them; when they rode on horseback they wore one suit and carried another to dress in at their journey's end, but in the coaches men do not require any second suit, as those they wear don't get spoiled, whereas when on horseback their clothes were won't to get spoiled, which done, they were forced to have new very often, and that increased the consumption and employment of the manufacturers, which travelling in coaches doth in no way do." The writer goes on to show how seriously this want of wear and tear in clothes is affected by people riding in coaches, for he says "that between London and the three principal towns of York, Chester and Exeter, not fewer than 18 persons, making the journey in five days, travel by them weekly (the coaches running thrice in the week) and a like number back." Another great nuisance they are responsible for, "not only did the gentlemen come to London much oftener than they need, but their ladies came with them or followed them very

closely, and when they are there they must be in the mode, have all the new fashions, go to the plays, balls, and treats, where they get such a habit of jollity and a love of gaiety and pleasure that nothing afterwards in the country will suit, and they must have all from London, whatever it costs." I think this poor man must not have claimed the Dunmow flitch, and it appears that our weaker vessels are constituted pretty much as they were 200 years ago. Before I close the coach it may interest some of you to know that, in the year 1700, York was one week's journey from London, Tunbridge Wells, now only an hour, took two days, and so on. The Flying Coach to Exeter arrived at its journey's end on the fifth night, and, so late as in 1768, it took a fortnight to get from London to Edinburgh. So much for the conveyance of passengers.

There was now some trade being done, not so much in the Lancashire cotton districts as in the Yorkshire woollen districts and Cheshire silk districts, and the whole of this produce had to be carried by horses with packs on their backs. A great deal of it came to Manchester as a commercial centre, but the roads were in such a frightful state that the task was both arduous and dangerous.

It was not until past the middle of last century that any serious attention was given to road-making, and as a profession it was quite unknown. The few men of eminence as engineers considered road-making as beneath their notice, and it was not at the time thought that Smeaton added to his reputation by condescending to make the road across the valley of the Trent in 1768. Road-making was generally left to anyone who cared to pitch rubbish into the ruts, to be crushed into shape by passing vehicles, until John Metcalf, a blind man of no trade, commenced the work scientifically and constructed about 200 miles of first rate roads, and thereby showed himself to be a great engineer and one of the most wonderful men this country has ever seen.

He was born in Knaresborough in 1717, and when six years old lost his sight by a severe attack of smallpox; strange to say this loss did not deprive the boy of his exercise, for he was not only one of the most active but most daring amongst his companions; while bird-nesting he would climb the worst trees

and became so fully acquainted with the country around Knaresborough that when he had grown into a big lad he one night acted as guide to a gentleman who had to walk from York to Harrowgate; he excelled in swimming, and one time recovered the bodies of two men who had been drowned in the river, he kept coursing dogs and was a fearless horse rider, not only often being amongst the first when hunting but once took the first prize at a steeplechase. It is easy enough to understand how a good horse could be trained to jump a fence when he came to it, but how to get him to it at the right place on a mapped out course which had to be run three times round was a daring thing for a blind youth to undertake. "Blind Jack of Knaresborough," as he was called, did it by procuring a number of dinner bells from the different inns in Harrogate, and posted a man at each of the flags which were fixed to stake out the course; this done he rode his horse by sound and jumped between the men with the bells wherever they were placed.

I call that an example of how to surmount a difficulty; how many of us give up at far less ones. Well, like most other men who are not born with a silver spoon in their mouths, Metcalf found that in order to live he must earn some money; not a very easy task for a blind man in those days; he took to the fiddle and for some time supported himself and family—for he married a bonnie bucksome lass—playing at meetings, mostly at hotels and gentlemen's houses; a musician in those days was scarce.

He travelled or rode to Whitby and sailed from there to London, taking his fiddle with him by which he mantained himself for several weeks. One night he arrived at one of the gates to the city of York and found himself barred out; he mounted the gate, unbarred it and led his horse through, in fact nothing seemed to stop this youth, for although blind he walked or rode freely about the country, went a second time to London, visited Windsor and Hampton Court, and walked back to Harrogate, completing the distance in less time than a Colonel Liddell did in his coach. Of course this is accounted for by the deplorable state of the roads, but the blind man walked the distance in six days.

The sight, if we may call it so, of London had enlarged his ideas, and with his fiddle savings he purchased a horse and chaise

and drove it for the public convenience, but his example was soon followed by others, so he next brought fish to Leeds and Harrogate, but this venture was unsuccessful and he lost his hard earnings and took to the fiddle again.

In 1745 he was engaged by William Thornton, Esq., of Thornville Royal, to collect a company of volunteers to join the King's forces and take part in the Rebellion; in two days he collected 140 men, out of which 64 were drafted as the intended number of the Company, and blind Jack played a march on his fiddle as he marched some distance in front of them, dressed in blue and buff. He spent some time with the soldiers and ran many risks in seeking in the enemy's camp for lost officers, and proceeded as far north as Aberdeen with the army. This visit showed him something new, for the clothing he found them manufacturing there, at once brought to his mind the feasibility of buying it in Aberdeen and selling it in North Yorkshire. Accordingly, he went to Aberdeen the following yearand bought what he thought would be useful, and made a considerable profit by the sales he made. He was also a horse dealer, and was acknowledged an uncommon good judge of a horse, and so this wonderful and indefatigable man went on in the ordinary ways of the world, never daunted.

He was 48 years old when the Act for making the road from Harrogate to Boroughbridge was passed, and as yet there were no acknowledged surveyors or contractors, but Metcalf here found another opening for his enterprising nature, and after some considerable trouble he obtained a contract to make three miles of this road, which he did to the full satisfaction of the trustees. Very soon after this he built a bridge at Boroughbridge, and increased his work in road-making and bridge-building until he was about 70 years old, or about 1787. Among his principal and most important were roads between Harrogate and Harewood Bridge, Chapeltown and Leeds, Broughton and Addingham, Mill Bridge and Halifax, &c., &c., in Yorkshire; between Bury and Blackburn, with a branch to Accrington, and many others in and about Ashton, Stockport, Whaley and Buxton, &c. In fact he constructed about 200 miles of road in about 22 years.

He was the first to get over boggy and marshy ground successfully by means of bundling heather and packing it for a

base to fix his road-making material upon—the identical plan followed years later by George Stephenson when carrying his railway across Chat. Moss. At one time he tried a little cotton spinning in Stockport, where he worked six spinning-jennies and a carding engine, with looms for weaving, but this was not a success, so he turned them over to his son-in-law, who was already in the business. Soon after this he retired to a small farm, where he lived until 1810, having attained the ripe old age of nearly 93 years, and left behind him, besides his wonderful works and general reputation, four children, twenty grandchildren, and ninety great-grandchildren.

I next come to a man who did a great deal for the opening up and development of the country, viz. James Brindley, who was born of very humble parents at Wormhill, near Millersdale, in 1716; he was early brought up under the disadvantages of having a father who paid more attention to bull-baiting and such like pastimes than to his farm work, and consequently kept his family in a state of great poverty, but James who was made of better stuff laboured diligently, and there sprung up within him a strong desire for mechanism, so in 1733 he apprenticed himself for seven years to a millwright at Sutton, near Macclesfield, named Bennett, who with his head men (who were like some in similar trades to-day) were very fond of refreshment. Fortunately Brindley did not give way to temptations in this way, and although there are many accounts of his stupidity during his early apprenticeship he by dint of extreme perseverance mastered his difficulties and let out his inborn genius. As one instance of his stupidity, he once had a waggon wheel to make, and when he had nearly finished he found he had fixed the spokes in the wrong way about, and consequently received his usual share of abuse from both his master and fellow workmen, but he quietly set to work to make another set of spokes and fix them right way about.

Notwithstanding this abuse, he, like all other engineers, was blessed with an even temper and good heart and did not bear any malice, for in the fourth year of his apprenticeship his employer had an order in hand for a paper mill on the river Dane, and he with his men worked and muddled on until they had worked themselves into a complete mess, and the more

they worked the more they were perplexed, until at last young Brindley heard that there was a similar mill working at Throstle Nest; so on the Saturday night he set out for his 25 mile walk, and obtained permission to inspect this machinery during the Sunday, which he did most thoroughly, for upon his return to Macclesfield on the Sunday night (on foot of course), he was able to overcome the difficulties, and so saved the reputation of his first employer.

In 1742 he commenced business for himself at Leek, where for some time he seems to have employed no one, even cutting down his own trees and cutting them up himself, but his reputation as a reliable millwright soon spread and his trade increased, but still he did not extend his facilities very much. He did a great deal of millwork in Staffordshire, Cheshire and Lancashire, and had to make or repair almost all kinds of machinery, from silk machinery to pottery stamps, and he was the one who suggested to Messrs. John and Thomas Wedgewood the advantage of stamping the flints in water.

He was next engaged in draining Clifton coal mines, which were then drowned out, and no one else could tackle them; to do this he made a tunnel through the rock about six hundred yards long, through this he led the river, and worked a water-wheel, which gave motion to the pumps. This scheme proved perfectly successful.

He had some early experience with the steam engine, but I don't think made much out of it; having been accustomed to do almost anything with timber he tried to make use of it even in the steam engine cylinder. Watt tried the same experiment, but like Brindley failed with it. There are some interesting memoranda in Brindley's note-books respecting one of his early engines, if not his first one. In 1757, after he had been at work about twelve months on his engine, he enters "Bad luck 5 days," "Bad luck 3 days," then "Midlin' luck" repeated for some time until the entries cease. Three or four months after this he makes several entries again, and things seem to be going better, until, on the 21st of the following April, he enters "to Rum, a bout o' drinking, 1s. 6d.," so that it appears as if he had been having a mild spree to drown his sorrow. He did not long indulge in his eighteen pennyworth, for in 1758 he filed a

patent for certain improvements in connection with steam engines and boilers, and, in 1763, constructed an iron steam engine for a colliery at Newcastle. But at this time his ingenuity seems to have been turned from engine building to canal making.

There is no doubt that canals did as much as any one thing in their time to open up and prevent the manufactures of the country from being crippled for want of carrying power, and James Brindley was the man who engineered the majority of these into successful existence. He made canals in nearly all parts of the manufacturing counties, and in these counties wherever you see a canal you will very seldom make a mistake by saying that its source was Brindley's head.

His first principal undertaking was the Duke of Bridgewater's canal from Worsley to Manchester, chiefly for the purpose of carrying coal in 1755, traffic between Manchester and Liverpool at this time being conducted by road or by barges on the river, and in many cases the cost was £2 per ton. All the same these two towns were increasing in population and importance and gradually becoming more dependent upon one another.

In 1757 the population of Manchester and Salford was only 20,000, and it was difficult to get materials either in or out of them, even provisions were often scarce, so bad were the methods of communication; for the same reason coals were scanty. Seeing this the Duke of Bridgewater called in Brindley to advise as to how his canal should be constructed, and we very soon have him surveying the route for this canal; in his plan he proposed carrying an aqueduct over the Irwell, and in 1760 an Act was passed empowering this to be done, but there was a very serious objection raised against this, principally to the necessity of Barton aqueduct. The Duke and Brindley were repeatedly appealed to, asking them not to attempt an impossibility—for who ever heard of water being carried over ships which were sailing underneath, and one worthy told the Duke that he "had often heard of castles in the air but never before saw where any of them were to be erected." However, neither of these men were to be daunted, and this length of the canal including Barton aqueduct was completed, and proved such a benefit to all concerned that it was considered one of the

wonders of the age, and the Duke decided to apply for an Act to empower him to continue his canal to the Mersey.

As an instance of the Duke's foresight and enterprise it is curious to note that he foresaw the great advantage his new project would be to both the leading Lancashire towns, Manchester and Liverpool, for in 1761 the goods then carried between them were only about 40 tons per week, and the cost and inconvenience of transport were such that he could see a good return for his outlay. It may be interesting to Ship Canal Shareholders to note that this canal was the chief cause of the two towns increasing so rapidly as they did, for in 1760 there were only 1,245 vessels entered Liverpool, and as a seaport it was a long way behind many others in this country. There was great opposition to the passing of this bill, 1762, but it was eventually pushed through with dogged perseverance such as we witnessed some few years ago, and the work was speedily pressed forward to completion.

But again like the Ship Canal the expenditure exceeded the estimates, and the Duke was so severely drawn upon that he had to see his bankers in London and borrowed £25,000, which was paid back in 1769. The canal itself was opened for traffic to Runcorn in 1767. Brindley still continued in his canal work and among others constructed the Grand Trunk Canal, in fact he continued hard at work until his untimely death in 1772, in the fifty-sixth year of his age.

I have said much more than I at first intended, but as I do not wish to trespass upon your patience I shall only allude to one man in particular, and I don't think I should be doing the title of Engineer justice if I did not mention the name of George Stephenson, of whom I think we all know sufficient to make it unnecessary for me to go into the details of his life; suffice it to say that he was the father of the railways, which it would be as impossible to dispense with as it would be to put a chicken back into its shell.

We have had many other examples of engineering of all classes during more recent years which I could not think of enumerating, but keeping in view the development of the country, year by year, century by century, from a pasture range to a cornfield and garden; alongside of agriculture there have

grown up handicrafts, trades and manufactures, by which the raw materials have been worked into tools and fabrics. The powers of nature have been converted into useful channels; wind, water and steam have become useful allies and servants. Bridle paths superseded by wheel-roads, rivers dug out and deepened or used to feed artificial channels of water communications, and from a land of horse vehicles has become one of steam trains and iron railroads. All branches of agriculture, trade and manufacture have been accelerated, until Britain became the world's school of industry and the world's workshop, all through the undaunted energy, skill and pluck of our engineers; and I trust every member of this Association will make it his first aim to excel in whatever he may undertake, so that our successors may be as proud as I am of the title engineer.

On the motion of the EX-PRESIDENT (Mr. John West), seconded by Mr. T. ASHBURY, a cordial vote of thanks was passed by acclamation to the President for his interesting address, which he briefly acknowledged, and the proceedings terminated.

DISCUSSION

ON THE

RELATIVE ECONOMY OF TRIPLE-EXPANSION, COMPOUND AND SIMPLE ENGINES.

INTRODUCED BY

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Assoc.M.I.C.E., M.I.M.E.,

OF MANCHESTER.

SATURDAY, 13TH FEBRUARY, 1892.

MR. PRESIDENT AND GENTLEMEN,

The object of the brief opening statement about to be given, is to evoke discussion on a subject which has been very freely used for that purpose during the past nine months by societies of a similar character to our own.

One of the results of these discussions has been the bringing out of many views as to what is the most important standard of steam engine economy; sometimes the economy in consumption of coal is taken as the standard; sometimes the economy of steam; and very often, the ultimate commercial economy including capital expenditure and wear and tear. Any one of these various standards is important, as well as being ample for the purposes of one night's discussion, therefore it might be well at the outset to define exactly what is the meaning of the word economy as used in the remarks which follow. There is one kind of economy belonging to a steam engine from which, when once settled, most of the other kinds can easily be deduced, and for the present it is intended to limit the word to that particular meaning. The economy of a steam engine is, therefore, to be measured inversely by the weight of steam used per indicated horse-power per hour; the most economical engine being the one which requires the least weight of steam for the given power.

Perhaps the leading question can be put more definitely in this way: Why does the triple-expansion engine use less weight of steam per indicated horse-power than either the compound or the simple engine? That the triple expansion engine does this needs no further proof than this: that prior to its introduction a consumption of 16lbs. of steam per indicated horse-power per hour was considered to be an excellent performance, though exceptional instances of less being required were recorded; whereas, since the introduction of the third cylinder, much more than 13·5lbs. would be called only a moderate result, and quantities as low as 12lbs. have been recorded on very good authority.

There is very little dispute about the general answer to the question; it is the particular or detail answer which is so difficult, and which often causes the expression of many different opinions. The general answer is this:—It is because initial condensation takes place in all practical steam engines, except those supplied with superheated steam, and the expanding of the steam through more than one cylinder enables the resulting mixture of steam and water to be used to better effect; providing that a certain limiting ratio between the initial pressure and the number of cylinders is not exceeded.

Is there any absolute economy of steam in the triple-expansion engine beyond that due to the increased pressure and consequent greater range of temperature between which the steam can be worked?

To settle this point a curve A, Plate 1, has been plotted from a formula, derived from another given on page 387 of "Rankine's Treatise on the Steam Engine." The ordinates of the curve represent lbs. of steam per indicated horse-power per hour, and the abscissæ give the absolute pressures in lbs. per square inch. The formula is as follows:—

$$W = \frac{33{,}000 \times 60}{J\left\{T_1 - T_2\left(1 + \text{hyp. log.}\frac{T_1}{T_2}\right)\right\} + \frac{T_1 - T_2}{T_1} H + R\ (P_2 - P_3)\ 144}$$

Where

W = pounds of steam per indicated horse-power per hour.

J = Joule's mechanical equivalent of heat,

T_1 = absolute temperature of the steam supplied to the engine = the temperature Fahrenheit + 461°.

T_2 = absolute temperature of the steam at the end of the expansion.

H = the mechanical value of the latent heat of steam at the given pressure (= L × 772).

R = actual ratio of expansion including all clearances.

P_2 = absolute pressure at end of expansion in lbs. per square inch, taken in this case at 6lbs.

P_3 = absolute back pressure due to condenser and passages, taken as 3lbs.

The formula gives the least weight of steam that could supply the heat necessary to do the required work when being used in a non-conducting cylinder, and represents the best result possible under the present system of using saturated steam. The curve shows that the minimum at 200lbs. absolute pressure, or 185·3lbs. by pressure gauge is 9·54lbs.; at 150lbs. it is 10·28lbs.; at 100lbs. it is 11·5lbs.; at 70lbs. it is 12·93lbs. The curve marked B is founded upon the result of a very careful trial made upon a triple-expansion engine working with an initial absolute pressure of 154lbs. per square inch, and using 13·6lbs. of steam per indicated horse-power per hour, or 3·46lbs. per hour more than the limit. The curve has been continued by taking this proportion, viz, 34·12 per cent., and adding it to the curve A at all points, and it shows that, considering the heat contained in the steam supplied to this triple engine, it was thermodynamically about equal to the very best compound working at 110lbs. absolute, and using 15lbs. of steam per indicated horse-power per hour. Better results from a compound than this have been recorded, but they were obtained generally by the use of slightly superheated steam, and are therefore outside the comparison. Curve C is obtained in the same manner from the published result of a test of a triple expansion engine made in Germany, when it was found that the engine used 11·85lbs. of steam per indicated horse-power per hour, while working at an absolute initial pressure of 155·7lbs. per square inch—a result better in every way than

anything yet achieved by the compound engine. The first question may be answered, then, in this way:—That the ordinary triple-expansion engine is about equal as a heat using machine to the best compound, and when more experience has been gained will probably be much better.

Has there been a decrease in the total range of temperature in each cylinder sufficient to account for the extra saving above the best performance of the compound engine? A very general opinion prevails that the whole of the advantages of the triple engine as a steam user are due to the reduction of the range of temperature, and the opinion is founded on the following hypothesis of the action of steam in a cylinder.

It is held that when steam is admitted to a cylinder which has been working long enough to have reached its normal temperature it comes in contact with surfaces such as the insides of the ports, the piston, the cylinder cover and the cylinder walls, all of which have been cooled down to the exhaust temperature by the previous stroke, consequently a portion of the incoming steam must be condensed to give up heat to these surfaces in order that they may reach a temperature nearly approaching that of the incoming steam. As the piston moves forward in its stroke it continually uncovers portions of the cylinder walls, which are cool from the exhaust going on on the other side of the piston—therefore condensation still goes on, the steam parting with heat which the walls of the cylinder take up. This goes on until the point of cut-off is reached after which there is a great change in the conditions. As soon as cut-off has taken place the steam begins to work by expansion, and steam should still be condensed, unless the weight of the expanding steam were sufficient to give up enough heat to perform the work by the fall in temperature alone. But as the steam expands and the temperature falls, the cylinder walls and the surfaces before-mentioned find themselves at a higher temperature than the steam, and heat consequently passes from them into the steam, the net result of these two opposing actions being generally, that the walls part with more heat than is required to perform work, the surplus being used in re-evaporating a portion of the deposited water; so that the indicator diagram accounts for a small percentage more steam

just before release than existed just after cut-off. When the exhaust port opens, the pressure and temperature rapidly fall and continue low during the whole exhaust period, and re-evaporation must go on very rapidly all the time; for it is a necessity that whatever steam entered the cylinder as steam, must leave it again as steam—not as water—except the amount required to supply the heat converted into work, and to make up for losses by external radiation; that alone can pass away as water, for if more water than that passed away the normal temperature of the cylinder would be increased by the latent heat set free when the steam condensed, and the increase would go on indefinitely. This is, in fact, the action which takes place for a short time when an engine is first started, but the cylinder rapidly reaches such a temperature that no more is condensed than is re-evaporated and then the temperature remains constant, except for certain periodical fluctuations in a very thin shell of the inside of the walls which varies above and below the mean at every stroke. If the engine be a simple one the whole of the heat contained in this re-evaporated steam is thrown away either into the condenser or into the atmosphere according as the engine is condensing or non-condensing: but if it is a compound engine then the steam so re-evaporated can be used over again and a portion of its heat is thus saved. It is easily seen that in any particular cylinder the amount of steam condensed in raising the temperature of a thin shell of the interior metal from the exhaust temperature to that of the boiler steam, will depend in some measure upon the weight of metal to be heated, and upon the number of degrees through which its temperature has to be raised. If the weight of metal can be reduced, or if the range of temperature can be diminished, then a proportionate saving in initial condensation should result. Now by adding to the simple engine a second smaller cylinder it is possible to reduce the range of temperature in each cylinder by one half, so that there should be very much less initial condensation in the compound engine than there was in the the simple one. Speaking broadly that is the commonly accepted reason why compounding, whether with two, three, four or more cylinders is advantageous.

The first difficulty met with in comparing this hypothesis with the actual facts as between the triple-expansion and the

compound engine is this: that it is very generally the case, that the maximum range of temperature in each cylinder of a triple-expansion engine exceeds the maximum range in the cylinders of the compound with which it is compared, and the percentage of initial condensation is mostly greater in the triple engine, though it does happen often that the actual weight of steam so condensed is considerably less than with the smaller percentage in the compound, owing to the smaller total weight required on account of the higher pressure. It is remarkable, and indeed almost beyond explanation, how so much steam can be condensed during the admission period, if range of temperature is so very important, for it frequently happens that compression is carried almost to the initial pressure, and the clearance surfaces ought, consequently, to be very nearly at the initial temperature before any steam is admitted, and the only chilling surfaces should be those of the cylinder barrel exposed by the motion of the piston. By the very valuable experiments on the variation of temperature of the cylinder walls in steam engines carried out for many years by Mr. Bryan Donkin, it is proved that only about one-tenth of the thickness of the cylinder varies in temperature at each stroke, and only a very thin shell approximates to the highest and lowest temperatures of the cycle, the action of the heat appearing to die away gradually into a sort of mean general temperature, approaching the external condition of the walls according as they are jacketted or not. Therefore the metal to be heated in the high pressure cylinder of a triple expansion engine would appear to be too small to effect such a large amount of condensation unless some other action was going on. Then there appears to be very little additional condensation in the remaining two cylinders in spite of their increasing size. It would naturally be expected that if 25 per cent. of steam were missing just before release in the small high pressure cylinder, more would be missing at the same point in the larger intermediate cylinder, and more still in the low pressure cylinder; but the actual facts are these, that the diagram from the intermediate cylinder generally accounts for five or six per cent. *more* steam than the high pressure, and the low pressure one about three per cent. less than the high. Hence it is concluded that range of temperature alone cannot make all the difference, since

it so happens that although the range is reduced by compounding, yet the weight of metal to be heated is proportionally greater, taking the whole engine, consisting of two cylinders and the receiver, or three cylinders and two receivers. The range of temperature in the receivers is not so great by any means as it is in the cylinders, but there is nevertheless a very important difference tending to cause initial condensation in them as well as in the cylinders—in fact, for a very considerable part of each stroke of the compounding cylinders the receivers act simply as very large clearance spaces, and whatever action goes on in the cylinders must also go on in the receivers. Therefore, some other cause for the saving must be sought for, beyond range of temperature. Indeed, so far from its being the fact that the lower the range the more economical the engine, it appears to be proved that so long as the maximum range in any particular cylinder does not exceed 95°, any reduction makes but little difference; the most economical range appearing to be about 88°.

What, then, is the principal cause of the saving?

To answer this question it will be advisable to follow the development of the compound principle from early days, and note the changes that have occurred.

In those days, with boiler pressures not less than 40lbs. per square inch, it was a very common custom to fix the cut-off not earlier than three-quarters of the stroke in the high pressure cylinder, and about at the same point in the low pressure cylinder. As pressures increased the advantages of compounding became more pronounced, though the proportionate area of the cylinders did not change much until after 60lbs. were reached—the high pressure cylinder being very commonly one-half the diameter of the low, or one-fourth the area; but with each increase in pressure the point of cut-off in the high pressure cylinder got nearer and nearer to half-stroke. A change in proportion began to take place after 60lbs. were passed, and as pressures gradually crept up towards 100lbs. the high pressure cylinder as gradually increased in size, the proportionate area changing from 4 to 1, to 3½ to 1, 3 to 1, 2¾ to 1, 2½ to 1, and even as low as 2 to 1; at the same time the point of cut-off was altered to a position nearer and nearer to the commencement

of the stroke. Note, now, the general tendency of this change. The tendency is to increase the range of temperature in the high pressure cylinder while keeping that in the low pressure cylinder at the same amount as it had almost from the commencement of the era of compounding. This seems to point to the fact that the range in the low pressure cylinder soon reached a limiting maximum, beyond which it was unadvisable to go. Now, the earlier the point at which cut-off takes place in the high pressure cylinder the greater is the proportion of the total work which that cylinder does. This is the important point in the argument, as will shortly be seen. The result of practical experience which has led engineers to increase the range of expansion in the high pressure cylinder, is also in accordance with what theory would suggest, though at first sight practice appears to be wrong; for it is a fact that a difference of temperature of 2·35 degrees at 175lbs. absolute pressure means a drop of 5lbs. in pressure, while at 75lbs. pressure the same range only means the loss of 2½lbs., and it seems as though the correct course would be to keep the range of temperature at the higher pressure as small as possible so as to save the pressure. But on searching more closely into the question it is found that the quantity of heat set free by the 2·35° fall in temperature is practically the same though the pressures are so different. Hence practice is right when it shows that as much range of pressure as possible should be got out of the steam, while the temperature range is limited. In other words, the higher the initial pressure the greater is the range of pressure with a given range of temperature.

The most important step in economy gained by compounding, either with two or three cylinders lies in this fact, that by using a high pressure cylinder it is possible to take a very large amount of work out of the steam without allowing its temperature to fall below a very moderate figure, say a fall of 95°. To take the same amount of work out of the steam by a simple engine would necessitate a range of no less than 220° assuming for the present that the initial pressure is 142 lbs.—for in any case it would be necessary to use a condenser whatever the degree of expansion might be. Part of the work so taken out of the steam is spent in doing work directly upon the crank shaft, but a much

greater portion is spent upon the steam in the intermediate receiver, heating it or keeping up the supply of mechanical work directly by a transfer of power through the steam to the intermediate cylinder, so that there is but slight reason for condensation in the remaining stages.

The actual power developed by the steam in the high pressure cylinder very greatly exceeds the net power shown by the indicator diagram, and though it is quite correct to estimate the useful effect of an engine from its indicator diagram, it is quite wrong to use anything but the total, or gross power, in investigations of the causes of any specified economy. The gross power is obtained from the indicator diagram by the ordinary method, but instead of measuring the pressures between the steam and exhaust lines of the diagram they are measured between the steam line of the diagram and the line of absolute zero pressure. That this method does really give the correct power which the steam is giving out, will scarcely be disputed when it is remembered that if the steam was carried direct from the high pressure cylinder to the condenser, the diagram would show the power correctly, and would then approximate to the gross power as calculated. It cannot matter, so far as the steam is concerned, whether the work being done on one side of the piston is being done upon the crank shaft wholly, or partly upon the crank shaft and partly upon an opposing steam pressure due to the back pressure in the receiver. If the back pressure were not there the work would all be done upon the piston rod, consequently when the back pressure is there the work is being done upon it instead. The same method of calculation should also be adopted with the remaining cylinders. To emphasize the argument take as an example the indicator diagrams shown in Plates 2 and 3. These were taken from a triple-expansion engine having cylinders 9·01 inches, 14·25 and 22·47 inches diameter by 2 feet stroke, and when making 121·6 revolutions per minute indicated :—

39·27	horse-power	in the high pressure cylinder.
42·04	,,	intermediate ,,
40·54	,,	low pressure ,,
121·85	,,	Total.

The boiler pressure was 157lbs. by gauge. This engine, used 12·86lbs. of steam per indicated horse-power per hour in the cylinders, and 1·24lbs. per indicated horse-power per hour in the jackets, or a total of 13·6lbs. The gross horse-power developed in the high pressure cylinder was 100 horse-power, and this was expended as follows: 39·27 horse-power went direct through the piston rod to the crank shaft, 60·73 horse-power were spent upon the steam in the intermediate receiver. If it is assumed that the work done during the admission period is really done in the cylinder and not in the boiler, then the condensation due to work will amount to no less than 17 per cent. of the steam admitted, an amount of water which must pass on through the remaining cylinders as water unless re-boiled by heat abstracted from the steam in the jackets or generated by compression.

Now, consider what happens in the intermediate cylinder. The conditions are quite changed here, for the work done in this cylinder up to the point of cut-off need cause no condensation, because the condensation necessary to supply the heat is going on in the high pressure cylinder and is accounted for there; after cut-off there might be some further condensation, because the steam then works entirely by expansion. Indeed it seems likely that if the water sent from the high pressure cylinder could be removed before it reached the intermediate receiver, the steam in the latter might actually be superheated by the compressive action of the high pressure cylinder, but as it is, the water present prevents that, by taking up the surplus heat and re-evaporating to a certain extent. Calculating the gross work of the intermediate cylinder in the same manner as described for the first cylinder, it is found to develop 86 horse-power, of which 60·73 are received directly from the first cylinder leaving only 25·27 horse-power to be given out by the expanding steam. The power is expended in this way: 42·04 horse-power go directly to the crank shaft and 43·96 horse-power are transferred to the second receiver and work in the next stage. Treating the low pressure cylinder in the same way it is found to develope 58·7 horse-power, and having received 43·96 from the other cylinder it is only called upon to take 14·74 horse-power from the steam. The power is used up thus: 40·54 horse-power go direct to the crank shaft and 18·16 horse-power are wasted

upon the back pressure in the cylinder and condenser, and are entirely lost.

If any objection should be taken to this method of calculating the horse-power and dividing the result, it should be remembered that engineers have adopted the method at all times in the history of the steam engine in dealing with the back pressure resistance of condensing and non-condensing engines, therefore, there seems to be no reason against the extension of a correct principle to the other cylinders of a series.

Collecting the results they stand thus :—

	Horse-power.
Work developed by steam in the high pressure cylinder	100
,, ,, ,, intermediate ,, ...	25·27
,, ,, ,, low pressure ,, ...	14·74
	140·01
Less work wasted on back pressure	18·16
	121·85

	Developed by steam. H.P.	Used on shaft. H.P.	Transferred. H.P.	Re-used. H.P.	Wasted. H.P.
High pressure cylinder..	100	39·27	60·73	..	..
Intermediate ,, ..	25·27	42·04	43·96	60·73	..
Low pressure ,, ..	14·74	40·54	—	43·96	18·16
	140·01	121·85			

These results agree with the observed facts better than any hypothesis based upon range of temperature alone.

In the first place the observed fact that there is a great deal of steam condensed in the high pressure cylinder, agrees with what would be expected from the large amount of power developed, whereas there should be less condensation according to the range of temperature theory. Secondly, the fact that the indicator diagram of intermediate cylinders almost invariably accounts for a greater percentage of the steam than either of the others is explained by the mutual action of the two cylinders. Thirdly, the fact that the low pressure diagram shows less steam—but only slightly less—than the high is explained by the addition of the small quantity of water condensed in doing

work by expansion in the intermediate cylinder to that carried over from the high pressure cylinder.

Mr. Bryan Donkin has observed by means of his glass apparatus called a "Revealer," that the steam in the first cylinder suddenly becomes very foggy, in the second only slightly more foggy, and in the final stage still more foggy, but not to any great extent. This would be expected from the proportionate energy taken out of the steam, viz. 100, 25·27 and 14·74. A sketch of this extremely simple piece of apparatus will be seen at Plate 4. It consists of an inner and an outer glass tube, fitted between two plates, and made steam-tight; the inner tube can be connected with the cylinder by means of the small cock in a manner which does not require explaining, and when the cock is opened it shows the rapid condensation and re-evaporation due to the cooling effect of the cylinder walls in a surprisingly convincing way. One thing it shows most clearly: whatever the amount of condensation at the commencement of the stroke, every trace of it is gone before the end of the exhaust period, and certainly no water remains. Indeed if water is put into the apparatus it rapidly disappears by boiling, not during the admission, but during the period from shortly after cut-off to the beginning of compression. This shows that the total cyclical effect of the cylinder metal by itself is to leave the cylinder drier at the end of the exhaust period, and not wetter as is often stated. And it should be so too, since every pound weight of steam condensed in a cylinder by the chilling effect of the metal at a constant pressure of 150lbs. absolute per square inch would give up 860·62 units of heat, leaving one pound of water containing 330·56 units, whereas when re-evaporation takes place due to a fall of, say, 100lbs. in pressure, the water will only hold 250·97 units, and 916·63 units will now be required to re-convert the water into steam. The difference between these two totals proves that there are $(330{\cdot}56 + 860{\cdot}62) - (250{\cdot}97 + 916{\cdot}63) = 23{\cdot}58$ units set free during the condensation and cooling more than are required for the re-evaporation. Of course it is not contended that the complete series of complex interchanges between the metal, the priming water, and superheating due to wire drawing and many other things, actually leave the cylinder drier; the argument only applies to the effect of the

cylinder walls by themselves, but it goes to show that range of temperature and initial condensation due to the effect of the metal, are not in themselves of such first rate importance as generally supposed.

In conclusion, gentlemen, you are asked either to assent to, or to combat the following statements based upon the arguments just ended :—

1st. That the triple expansion steam engine is somewhat better as a heat using machine than the compound engine; regard being had to the quantities of heat contained in the steam when at the pressures found by experience to be those most suitable to each kind of engine.

2nd. That the range of temperature in triple expansion engines is generally as great per cylinder as in the compound.

3rd. That a range per cylinder of about 95° seems about the economical limit, but up to that amount its effect is not important.

4th. That the triple expansion engine does not depend for its greater economy upon any reduction of temperature range alone, and that such range does not account for the very considerable initial condensation known to take place.

5th. That the important cause of economy in the triple expansion engine and in the compound is the use of a high pressure cylinder, in which a very great proportion of the work of the engine can be done while the steam is at a high temperature, and with only a moderate range of temperature. The triple expansion engine has the advantage of such pressures that great expansion can take place without detrimental fall in temperature.

6th. That moderate initial condensation in the high pressure cylinder is not particularly important, where the re-evaporated steam can be used again, but is very important in the low pressure cylinder, because all the heat given up after release by re-evaporation is thrown away in the condenser. For the same reason it is best to use jackets —when any are used—upon the first two cylinders,

where the heat imparted to the steam during the exhaust stroke can be used in the next cylinder. Jacketting the low pressure cylinder may save initial condensation and may be useful as a warming-up apparatus, but as the difference in temperature is greater during exhaust, the flow of heat from the jacket will more than counterbalance the saving.

DISCUSSION.

Mr. ALFRED SAXON said that he rose for the purpose of initiating what he thought would prove to be an interesting discussion. Their thanks were due to Mr. Jenkins for having provided them with material for discussion, as there were several points advanced to which exception could be taken, as well as others to which confirmation might be added. In reference to the tests which had been mentioned in the paper he thought that the one selected by Mr. Jenkins was the best, viz., the weight of steam used per indicated horse power per hour, many other forms of tests being quite fallacious, such as the pounds of coal per indicated horse power per hour, as it has been distinctly proved that you might have an economical engine both in design and workmanship, showing poor results taken upon this basis through the boilers having inefficient evaporating capacity, whereas taking the weight of steam used "as a test," the relative efficiency of the engine and boiler could readily be ascertained and determined. The sooner engineers generally adopted such a basis as steam consumption against that of coal consumption now generally used for calculating the results of tests the better it would be, and the more reliable would be the tests as the quality of coal used and value of same vary in almost every case.

As regards the comparison of a compound engine with a triple expansion engine he was of opinion that Mr. Jenkins had certainly not done the compound justice. For instance, the only comparison he had made of a compound engine was with

one working at 110lbs. pressure, against two triple expansion engines, one of which was working at 154lbs. pressure, and the other at 155lbs. per square inch. Was it not possible to have selected for comparison a compound engine with cylinders properly proportioned for working at 155lbs. per square inch? then the comparison would have been much fairer, and the difference in results would have been, in his opinion, nearer between the compound and triple than the results given.

With reference to the proportions of cylinder given by Mr. Jenkins for compounding, where he stated that the proportionate area did not change much until after 60lbs. was reached, the high pressure cylinder being very commonly one-half the diameter of the low, or one-fourth the area, and as pressures gradually crept up towards 100lbs., the high pressure cylinders as gradually increased in size, the proportionate area changing from 4 to 1 to 3½ to 1, 3 to 1, 2¾ to 1, 2½ to 1, and even as low as 2 to 1, the cut off being altered to a position nearer and nearer the commencement of the stroke. He entirely differed from Mr. Jenkins as to these proportions at the higher pressures, and said it would be difficult to find in any modern compound engine cylinders with a greater area than 3 to 1.

Again he differed with Mr. Jenkins in his conclusion on the compound engine, where he mentioned an early cut-off in the high pressure cylinder being advantageous; this of course depended somewhat upon the proportion of the high to the low pressure cylinder, and also the load. He maintained that the working of an engine economically largely depended upon the work it had to perform, and if an engine were too large for its work and steam was being cut off early, such an engine would be working at a loss; on the other hand, if an engine was too small for its work, and steam was being carried too far in the stroke before being cut off, the best results would not be obtained owing to the excessive volume of steam to be dealt with by the condenser.

Any existing compound engine working with too early a cut-off, and with no likelihood of the load being increased, would work more economically, in his opinion, with the high pressure cylinders reduced in size, thus allowing of a later cut-off being used.

One advantage in the triple expansion engine over the compound engine not referred to by Mr. Jenkins, was that with the same size of a low pressure cylinder on a triple expansion engine working at 150lbs. pressure, as against the compound engine at 100lbs., was that an increased load of from 20 to 25 per cent. could be got out of the triple expansion engine with the same expenditure of coal, a mean pressure on the low pressure cylinder of 24 or 25lbs. at 100lbs. pressure in the compound engine being the general practice, whereas 30lbs. of a mean pressure on the low was the general practice with triple expansion engines working at a fixed load for mill purposes. An economy of 20 to 25 per cent. might be considered as being the result of triple expansion at 150lbs., as against the compound at 100lbs., with the same load in each case.

There are also other advantages to be gained by the use of the triple expansion principle over the compound, which are very important with reference to old engines, viz., the great reduction of the strains by bringing the increased boiler pressure to bear on a very much smaller area of cylinder, the strains being reduced below that of a compound engine for doing the same amount of work.

It seems to many present a long time since boiler pressures of 100lbs. were in force, but he came across a paper read by his father (Mr. George Saxon) before the Association in 1873, which contained the following remarks :—" Whilst speaking of boilers, I may just remark, that two or three years ago having taken a contract to supply a pair of compound engines, and my customer having determined on giving the order for the boilers to a firm who make it their especial business, he introduced me to the senior partner, in order that I might explain to him what kind of boilers it was desirable he should have. I insisted they must be plain, practical simple boilers; and to carry a working pressure of 100lbs. to the square inch. The greatness of the pressure caused him to shake his head, and ultimately he took a week to consider of it, at the end of which time we again met, he smiled, and produced his specification, which was accepted. Since that time the same firm has made a number of similar boilers, and I believe they are quite as safe as those which they formerly made to carry a much lower pressure."

That day he had been reading in the Oldham papers a description of the work this particular firm at present had in hand, comprising large boilers to work up to 200lbs. pressure for the triple and quadruple engines now being built in Lancashire.

In his opinion the progress of triple and quadruple expansion engines for land practice had been more impeded by boiler makers than engineers, because of the difficulty of making large Lancashire boilers to work safely at the high pressures required. From the moment this was determined, and marine practice had proved beyond doubt the economy of the principle of using high pressure steam, engineers were prepared to recommend and utilise these pressures with results that up to now had proved satisfactory, and as more experience was being gained as to the best proportions, and the best designs, greater results would be achieved in the future.

Mr. E. G. CONSTANTINE concurred with Mr. Jenkins in the remark that taking the quantity of steam used by the engine was the best test of its efficiency. In considering the work done by an engine it was essential to separate the machine from the boiler because the latter was often responsible for great waste. Recently he came across a case where the indicator diagram showed a consumption of 25lbs. of steam, but the coal consumption was 6·1lbs. per horse-power.

It appeared to him that the whole pith of the question of triple or quadruple expansion lay in the enormous number of expansions which could be obtained between the initial pressure and the terminal pressure. If one cylinder sufficiently large to utilize the available high pressure could be made, great economical results would probably accrue, were it not that there were serious practical difficulties in the way.

As regards the general adoption of triple expansion engines ashore, he was surprised that builders of land engines had not given more attention to it many years ago, as the economy resulting from their use on shipboard was conclusively demonstrated so long ago as 1874. He could only account for the apparent apathy by the fact that on land the economy was represented by the decrease in the amount of fuel used only, while the saving of fuel represented a much greater economy to

the shipowner as the cargo-carrying capacity of the vessel was also increased.

Concluding, Mr. Constantine said he was of opinion that the very best compound engines working ashore were nearly or equally as economical as the ordinary type of triple expansion engine used at sea. To his mind however for smoothness of working nothing was superior to the three-crank engine.

Mr. A. G. Brown said that, referring first to what the two preceding speakers had said he thought Mr. Saxon was entirely mistaken in stating, "that with the compound engine the average pressure referred to the low pressure cylinder would not exceed 25lbs. per square inch, while with the triple expansion engine the referred pressure would equal 30lbs. per square inch of the low pressure piston." This depended entirely on the pressure at the start. If they were working with 100lbs. boiler pressure it might not be advisable to carry more than 25lbs. average pressure when referred to the low pressure piston, but if they were working with 150lbs. boiler pressure, the same as the triple expansion engine, it certainly was advisable to carry a greater average pressure or the engine would not be economical, and he certainly did not think it fair to the engines to compare a compound engine working with 100lbs. boiler pressure, with a triple expansion engine working with 150lbs. pressure.

Referring to what Mr. Constantine had said about the impossibility of getting the same number of expansions in a single cylinder engine, as in the compound or triple expansion engine, he would state that this was perfectly easy to do, but was not advisable on the score of economy. In fact if they simply used the low pressure cylinder of the compound or triple engine and admitted the same quantity of steam to it as was usually admitted to the high pressure cylinder, they would have the same number of expansions, although, owing to the increased initial condensation, they would not get the same power nor the same economy.

He happened to have assisted in some tests of a simple steam engine working with 180lbs. boiler pressure, where they were able to get as many as 20 expansions, and as few as $1\frac{1}{2}$, that is they could cut off at less than $\frac{1}{20}$th of the stroke, or as late as $\frac{2}{3}$

stroke, and they found they obtained the best results when cutting off at about ⅛ of the stroke. From the lack of proper appliances for determining the exact quantity of steam passing through the cylinders they could not determine whether the loss was due altogether to cylinder condensation or not, but inferred that it was largely due to the large percentage of ineffective work done. Such a small amount of effective power was obtained while the gross power was pretty large; and in this connection he would state that in tests of this kind the indicator diagram should not be used as a basis for calculation, the effective work accomplished being the only true measure of the engine's performance. It should always be remembered that the friction of an engine was practically constant in amount at the same speed, no matter what indicated power may be shown, and when testing with very short cut-off the friction of the engine may be 90 per cent. of the indicated power, while with full loads it would be but 8 or 10 per cent.

As to the paper, he thought it was an excellent one, and deserved their best consideration, and he only regretted that he had not received it in time to go more fully into the various points raised, as these were matters that could not be taken up and discussed thoroughly without considerable reflection. He had only been able to look the paper over that afternoon and therefore his remarks would be rather superficial.

Mr. Jenkins, after alluding to the quantities of steam required for the compound and triple expansion engines, asks "Is there any absolute economy of steam beyond that due to the increased pressure and consequent greater range of temperatures between which the steam can be worked?"

He believed that there was, but to prove this would require a careful review of the whole matter, and he would first ask Mr. Jenkins, if the diagrams as shown in the engravings accompanying the paper were correct? He had calculated from them that the steam accounted for by the indicator was but 9·1lbs. per horse-power per hour, out of 13·6lbs. actually used,* leaving a balance of 4·5lbs. to be accounted for in some way. Mr. Jenkins

* The actual amount of steam passed through the cylinders was only 12·36lbs. per indicated horse-power per hour, as the jackets accounted for 1·24lbs. For the steam shown by the original diagrams see the last Table in Prof. Goodman's remarks.—W. J. J.

accounted for 17 per cent. of the total steam used being condensed in doing work in the high pressure cylinder (supposing that none of the work was done in the boiler), but here was 33 per cent. of the total steam to be accounted for, or an addition of 50 per cent. to the amount accounted for by the indicator; when he observed such a large percentage unaccounted for, he concluded that the diagrams were incorrect, except perhaps as to general appearance. He also did not concur in the statement that none of the work was done in the boiler, and thought that it could easily be proved that all the work accomplished up to the point of cut-off was done in the boiler, and as this amounted to half of the gross work shown in the high pressure cylinder, there would be but 8½ or 9 per cent. of the total steam condensed in doing the remaining work there, *i.e.*, the work done after the cut-off had taken place; this left a still larger percentage (according to the diagrams) to be accounted for by initial condensation, a much larger amount than he had ever noticed before, and it confirmed his conclusions that the engraver had not been sufficiently accurate in reproducing the diagrams.

Now there was one point which should not be overlooked. The engine mentioned developed 100 gross horse-power in the high pressure cylinder, out of which only 40 horse-power was effective. If this cylinder was working as a simple engine with the same back pressure, they would have the same quantity of steam used to develop 40 indicated horse-power, and it would use 41·5lbs. of steam per indicated horse-power per hour, the cylinder condensation and heat converted into work remaining precisely the same. But if, instead of taking such unfavourable conditions, it was assumed that the engine was working as a simple condensing engine, under good conditions, and with the ordinary back pressure to be expected, it would develop 95 indicated horse-power in the single cylinder, while the range of temperature would be about 225deg., instead of the 95deg. in the triple engine. The initial condensation would therefore be greatly increased, while the indicated power would be but 95 instead of 122, or a loss of 27 horse-power, equal to 22 per cent. of the indicated horse-power of the triple engine, or 28½ per cent. of the indicated horse-power of the simple engine.

From the time of the very first practical steam engine made, all of the important improvements devised had resulted in reduced initial condensation in the cylinders, and it was this that effected the saving or made the engine more economical. If any one interested in the subject would go carefully through the history of the steam engine, they would very quickly note this point. The experiments of Messrs. Emery & Isherwood, at the Brooklyn Navy Yard, with engines having both non-conducting glass cylinders, and ordinary iron ones showed very large savings for the glass cylinders under all conditions, the saving being due only to the reduced initial condensation, which is the sole reason why the employment of a greater number of cylinders was more economical with higher pressures of steam. The reduced initial condensation, over what would take place in a single cylinder working with the same steam pressure, permitted an increased number of expansions. It was certain that with the ordinary good engines in use, there was a maximum range of temperature which should not be exceeded in each cylinder to get the best results; and there must also be a certain minimum range, less than which it does not pay to go, otherwise the same number of expansions of steam (at any pressure) in one, two, or three cylinders would give practically the same results, barring the losses due to clearance and ineffective work done.

There were certain wastes or losses inherent in every steam engine cylinder, the more prominent being from the clearance spaces and the ineffective work done; and the more cylinders used the more losses from these causes, and these losses could only be balanced by the saving from reduced cylinder condensation. The increased number of expansions depended on this reduction.

With low pressures of steam and consequently small ranges of temperature the saving in initial condensation that would be effected in two or more cylinders, would not balance the losses from the causes above mentioned. It was therefore not advisable to use a large number of cylinders with a low pressure of steam, and it had been pretty clearly established that a good compound engine was not as economical as a good simple engine at 50lbs. pressure; it was also pretty clear that it would not be advisable to use a triple expansion engine at 100lbs. pressure of steam; as in neither case was there sufficient range of tem-

perature to be worked through to save, in initial condensation, an amount equal to that wasted on the greater number of cylinders.

As regards the statement that cutting off shorter in the high pressure cylinder was more economical, he quite agreed with Mr. Saxon that, after passing a certain point, it was not the case, as such a small amount of effective work was accomplished, compared with the total work done, that the loss from that would exceed anything gained by the increased number of expansions.

Respecting the cyclical effect of the cylinder metal itself, this, Mr. Jenkins stated, "is to leave the cylinder drier at the end of the exhaust period," due to the less number of units of heat contained in each pound of saturated steam at the lower pressure, or in other words this meant that the steam must be superheated at that time; but Mr. Jenkins had evidently neglected to take into account the units of heat converted into work, which must be taken from the steam itself, as there was no other source of supply, and this was only partially replaced by the lessened heat units required per pound of steam, so that in any case there must be water with the steam discharged from the cylinder.

Mr. Jenkins's conclusions were in the main correct, but the 2nd one, *i.e.*, "That the range of temperature in triple expansion engines is generally as great per cylinder as in the compound," left an erroneous impression, because the two engines were not compared when working with the same pressures of steam. Compound engines have been made to work with even higher steam pressures than the ordinary triple expansion engines are using, and Mr. Brown had seen some large compounds made to work with 200lbs. pressure; he was not able to give exact information regarding the results obtained, but was informed that the results did not equal the expectations.

Mr. A. Rea was of opinion that the previous speakers had missed the principal points in the paper. In discussing a question of this kind it should, he contended, be borne in mind that steam was not a permanent gas, but was subject to two natural laws, radiation and condensation. It was therefore essential to treat the steam engine as a heat motor pure and

simple. This was the great idea laid down by Joule, and in no other way could a right solution of the subject be obtained. The question therefore before the meeting was how to utilize the units of heat or force in the various pressures of steam used, and what was the most economical pressure to adopt. It was just possible that the Simple engine would be found most efficient for certain pressures, the Compound more efficient for higher pressures, and the Triple-expansion engine even more effective. There was also the question of friction that might be discussed. He had made, a short time since, a few experiments with drying the steam by passing the steam pipe through a small furnace, but could not off-hand lay the results before them. Seeing that Prof. Goodman was present, perhaps a few words from him on this important question would be appreciated by the members.

Mr. JOHN TAYLOR was disappointed that Mr. Jenkins had not given them more illustrations and comparisons of the work done by the triple expansion and compound engines respectively. From what he had seen of the adoption of triple expansion engines in the district of Oldham, the general saving seemed to be about 12 to 15 per cent. At the same time, he did not think it was correct to attribute the whole of the saving simply to the conversion of an engine into a triple expansion engine, for the simple reason that probably in the original circumstances the engine may not have been suitable for the demands made upon it.

Mr. S. BOSWELL remarked that as two of the speakers had charged the boilermaker with being behind, and not capable of supplying boilers sufficiently strong and suitable for high pressures, and considering that a great many of the members were not engine builders, he was anxious to show them that the boilermaker was not behind in the great advances in pressure. Twenty-five years ago many boilers were made and working at 80lbs. when only 70lbs. were wanted on the engine piston, at which time engineers could not get an initial cylinder pressure within 10lbs. of the boiler pressure. Our late and esteemed member, Mr. D. Adamson, was admitted to be the father of triple and quadruple engines ashore, and he had told them that it was not a question of boiler pressure, as he could always arrange

that; the great question had always been how to deal with the steam in the cylinders. Mr. Boswell remembered the steamship "Propontis," and believed that the failure was not due to the boilers or want of pressure. During the years 1869 to 1872 many boilers were made in Manchester for a daily working pressure of 150lbs. It might interest the meeting to know that he had very recently had a successful hydraulic test of 850lbs. on a boiler, and if only half of this were used as working pressure, 425lbs. would be at the call of the engineer, while a working pressure of 500lbs. was certainly not unknown. With engineers who were also first class boiler makers, the question of boilers was only a secondary consideration, and those who did not make boilers had only to go to a first class firm, say what was wanted and offer a fair price, and they could be supplied.

Professor GOODMAN (Leeds) observed that every question relating to the thermal economy of the steam engine resolved itself into that of how to reduce the internal condensation in the cylinder or working chamber of the motor. Since the introduction of the Savery engine the consumption of steam per horse-power per hour had been reduced to about $\frac{1}{12}$ of what it was formerly; each improvement had mainly, if not wholly, been due to the reduction in the condensation of the steam. In the Savery engine about $\frac{7}{8}$ths of all the steam supplied was condensed; according to Smeaton, not far short of 170lbs. of steam were used per horse-power per hour, and even at the present day the Pulsometer, the modern representative of the Savery engine, used over 200lbs. of steam per horse-power per hour*.

Newcomen somewhat reduced this enormous condensation, by not allowing the steam to come in direct contact with the cold water he was pumping, but still he used his cylinder as a condenser, hence much of the incoming steam was instantly condensed.

*A convenient approximate formula for calculating the weight (W) of steam used per horse-power per hour by a Pulsometer is $W = \frac{1{,}760 \times \text{rise of temperature.}}{\text{Lift in feet.}}$ The rise of temperature of the water lifted should be expressed in Fahrenheit degrees. This is not an empirical formula, but it is unnecessary to go into the details as to how it has been arrived at.

Watts's great invention of using a separate condenser owed its success entirely to the fact that he thereby largely reduced the initial condensation.

Brindley and Smeaton attempted to still further reduce it by using wooden cylinders; being bad conductors of heat, they would have undoubtedly succeeded had it not been that wood was an unsuitable material where heat, moisture, and rubbing were required.

Later experimenters had endeavoured, with more or less success, to reduce the condensation by steam jackets, superheated steam, and by reducing the range of temperature in each cylinder by carrying on the expansion in two or more cylinders; that, indeed, was the question before them that to-night.

The author of the paper showed that the use of two or more cylinders had unquestionably reduced the consumption of steam, but whether the reduced consumption had been due to the reduction in the initial condensation was not yet proved, it being far more probable that the initial condensation was as great in the high pressure cylinder as before, but that the steam initially condensed was re-evaporated later on, and used in the following cylinders.

The author of the paper appeared to have come to the conclusion that the temperature of the cylinder walls had but little effect on ultimate economy; in the main he may be right, but yet they must not ignore the fact that experiments on all hands showed that the temperature of the walls had a very important effect on the initial condensation. Take for example, the influence of steam jackets, they, by keeping the walls hotter, very materially reduced the initial condensation. The following experiments were made on an engine of about 100 horse-power:

Ratio of expansion		1	1·3	1·88	2·65	3·35	4·0	4·53	5·5	6·3	
Initial Condensation	No Jackets	8	10	13	16	20	23	25	30	35	Per cent.
	Jackets ..	3	4	4	5	6	8	10	11	11	

It was worthy of note, however, that because the engine was unjacketed, the initial condensation was practically the same when it was working as a condensing engine as when working

non-condensing—*a priori* they would certainly have expected to find slighly more initial condensation in the former than in the latter case.

A still more striking case of the effect of the temperature of the cylinder walls on initial condensation was to be found in Mr. Donkin's experiments (Institute Civil Engineers' Proceedings, xcviii., 251) on cylinders externally heated with gas flames.

Pounds of Steam used per indicated horse-power per hour.		Initial Condensation. Per cent.	
With Gas flame playing on Cylinder.	Without Gas flame.	With Gas flame.	Without Gas flame.
Non-condensing .. 34·1	44·4	None. Steam superheated	20 per cent.
Condensing ..... 30·3	38·5	10 per cent.	26·5 per cent.

In another case Mr. Donkin found that he could reduce the initial condensation by injecting large quantities of grease into his cylinder, presumably the grease settled on the surfaces of the piston and cover, and formed a coating which was a bad conductor of heat.

Other experiments by Emery in the United States showed that initial condensation may be reduced by covering the cylinder covers and piston with a bad conductor of heat; both of these experiments tended to show that the temperature of the walls had at least something to do with the initial condensation.

Some years ago Messrs. Clayton & Shuttleworth placed the cylinders of their portable engines in the smoke box in order to keep the walls hot, and so prevent initial condensation. The plan was excellent although it was not altogether a success, probably because the soot deposited on the surfaces and prevented the heat from passing; surely it would be worth while to provide an automatic scraper to keep the walls clean, similar to the scrapers used on Green's economiser.

The preceding remarks certainly went to prove that the temperature of the cylinder walls had a very marked effect on initial condensation. It may be well now to look at another phase of the question—that of the effect of surface. It had been well known for years that the percentage of initial condensation

increased as the range of expansion increased, and this fact was often quoted as a proof that initial condensation was due to the range of temperature in the cylinder. That, however, was not strictly true, for it must be remembered that as the range of expansion increased so the total weight of steam admitted correspondingly decreased; as a matter of fact the weight of steam actually condensed was practically constant at all grades of expansion, as may be seen from the following tables :—

The weight of steam actually condensed had been arrived at thus :—

Let x = the weight of steam actually supplied to the cylinder per stroke,

y = the percentage of initial condensation,

r = the ratio of expansion including clearances,

and let the total capacity of the cylinder be taken as 100lbs. of steam (including clearances).

At cut off we have $\frac{100}{r}$ lbs. of steam in the cylinder

$$x = \frac{100}{r\left(1-\frac{y}{100}\right)}$$

Weight actually condensed $= x - \frac{100}{r}$ lbs.

" " " $= \frac{100\,y}{r\,(100-y)}$ lbs.

Ratio of expansion ..	1	1·3	1·88	2·65	3·35	4·00	4·53	5·5	6·3
Initial condensation..	8	10	13	16	20	23	25	30	35
Weight of steam condensed in lbs.	8·7	8·5	8·0	7·2	7·5	7·5	7·4	7·8	8·5

Ratio of expansion ..	1	1·3	1·88	2·65	3·35	4·00	4·53	5·5	6·3
Initial condensation..	3	4	4	5	6	8	10	11	11
Weight of steam condensed in lbs.	3·1	3·2	2·2	2·0	1·9	2·2	2·4	2·3	2·0

Ratio of expansion ..	2	2·5	3	3·5	4	4·5	5	5·5	6	6·5
Initial condensation..	13	16·5	20	23	26	28	30	32	33	35
Weight of steam condensed in lbs.	7·5	7·9	8·3	8·5	8·8	8·6	8·6	8·5	8·2	8·3

Although these figures were not quite so regular as one could have desired, yet they seemed to show that the weight of steam initially condensed was fairly constant for all grades of expansion, and probably depended rather on the extent of surface in contact with the steam before the piston began to move; that being the case we should expect to find more initial condensation in small engines where the ratio

$$\frac{\text{Surface of cylinder in contact with steam at admission}}{\text{Volume of steam in cylinder at admission}}$$

was greater than in large engines—which was certainly borne out by experiment.

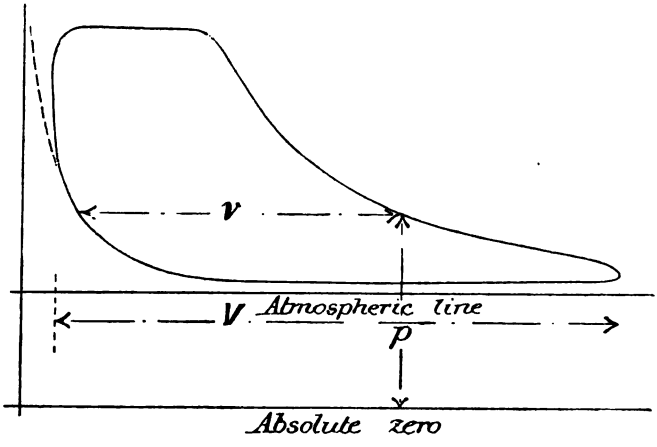
If then the surface had anything to do with the initial condensation we should expect to find that the condensation would increase as the time of contact of the steam and the surfaces increased. This point was abundantly proved by Willan's experiments (Institute Civil Engineers' Proceedings, xciii., 128).

Ratio of expansion	2·0	2·5	3·1	3·6
Steam per I. H.P. per hour, revs. 400	36·15	30·28	25·88	24·75
" " " 210	38·79	32·98	26·05	30·06
" " " 115	44·65	40·04	32·93	30·06

There was a point that was often overlooked in connection with the question of the "missing quantity" or initial condensation, they were spoken of as being one and the same quantity; the steam shown by the indicator was measured, and the feed water as supplied to the boiler; the difference between them was called "initial condensation." How about leaky pistons? The experience of the speaker was, that few if any pistons were even approximately tight, even if they were tight when standing, they frequently leaked when running, but if leakage did occur, it would entirely upset any calculations on initial condensation. He was of the opinion that some of the loss that was credited to initial condensation may be due to leaky pistons.

The value of engine trials would be very much increased if the weight of steam as shown by the indicator were given in conjunction with the feed measurements, such data was comparatively rare and was very much wanted; probably the lack of

information on this point was due to the difficulty of making the determination by the usually accepted method. He had recently worked out a very simple method which he believed would greatly facilitate such calculations.



In the annexed figure—

Let V = working volume of the cylinder in cubic feet,
L = length of stroke in feet,
A = area of piston in square inches,
P_e = mean effective pressure on the piston,
N = number of revolutions per minute,
p = absolute pressure at which vol. v is measured.

For a compound engine $P_e = P'_e + P''_e\ r$	P'_e = mean effective pressure on H.P. piston. P''_e = do. on L.P. piston. P'''_e = do. on third piston.
For a triple expansion engine $P_e = P'_e + P''_e\ r + P'''_e\ r'$	$r = \frac{\text{area of L.P. piston.}}{\text{area of H.P. piston.}}$ $r' = \frac{\text{area of third piston.}}{\text{area of H.P. piston.}}$

Let $x = \frac{v}{V}$

Volume of steam used per hour at the pressure p

$$= \frac{120 \text{ L A N } x}{144} \qquad (i.)$$

$$\text{Indicated horse-power} = \frac{2 \text{ P}_e \text{ L A N}}{33{,}000} \qquad (ii.)$$

Volume of steam used per indicated horse-power per hour at the pressure $p = \frac{(i)}{(ii)} = \frac{18{,}750\ x}{\text{P}_e}$

If the volume v be measured from the compression line of the card, no allowance need be made for clearance; if there be only a small amount of compression it may be measured from the compression line produced as shown dotted, but if there be no compression, it must be measured from the ordinate of the diagram, set off at the right distance to allow for clearance, *i.e.*, the distance from the ordinate to the beginning of the card must represent the clearance volume on the same scale as V represents the working volume, or clearance may be allowed for thus—

$$\text{Let } c = \frac{\text{clearance volume}}{\text{working volume}}$$

c = about 0·02, in large Corliss engines.
0·12 in badly designed small engines.
0·07 may be taken as a mean—

When there is no compression, and when v has been measured from the card and not from the ordinate—

Volume of steam used per indicated horse-power per hour at the pressure $p = \frac{18{,}750\ x\ (1 + \frac{c}{x})}{\text{P}_e}$

Let v_o = number of cubic feet in 1lb. steam at the pressure p.

Then $p\ v_o^{1·065} = 478$ foot lbs. (See Standard Works on steam engine.)

Then

$$\left.\begin{matrix}\text{Weight of steam used}\\ \text{per I.H.P. per hour}\end{matrix}\right\} = W = \frac{\text{volume per I.H.P. per hour}}{\text{Number of cubic feet per lb.}}$$

$$W = \frac{13{,}750\ x}{P_o^{1\cdot065}\sqrt{\frac{478}{p}}}$$

(A) When v is measured from the compression line, or when there is no compression, from the ordinate.

or

$$W = \frac{13{,}750\ x\ (1 + \frac{c}{x})}{P_o^{1\cdot065}\sqrt{\frac{478}{p}}}$$

(B) When there is no compression, and v is measured from the beginning of the card and not from the ordinate.

This, however is an inconvenient expression to use, on account of the fractional root, it may be simplified thus—

$$W = \frac{13{,}750\ x\ p}{K\ P_o} \qquad \text{(See note (A) above.)}$$

or

$$W = \frac{13{,}750\ x\ (1 + \frac{c}{x})\ p}{K\ P_o} \qquad \text{(See note (B) above.)}$$

where $K = p\ v_o$ and has the following values :—

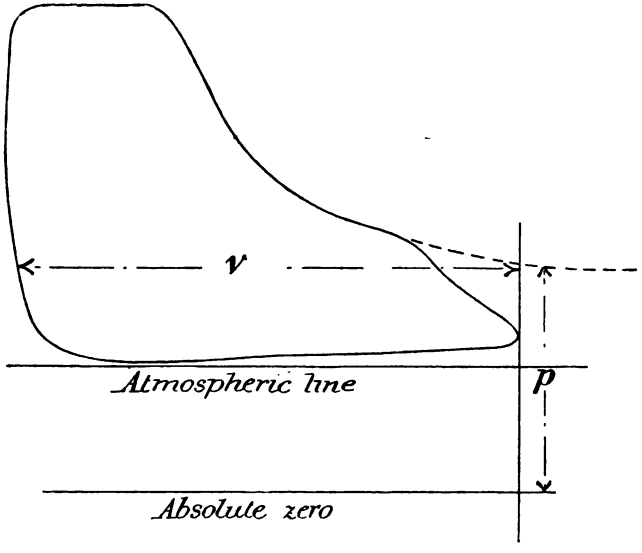
Values of K

p (lbs. □ in.)	K
Atmospheric	387
17	390
20	395
25	400
30	404
35	408
40	412
45	415
50	418
60	422
70	426
80	430
90	433
100	437

It will thus be seen that there is no need whatever to determine the diameter of the cylinder, the stroke, or the revolutions,

in order to get the steam used per indicated horse-power per hour.

In order to get a rough idea of the weight of steam an engine is likely to use per indicated horse-power per hour, produce the expansion line thus:—

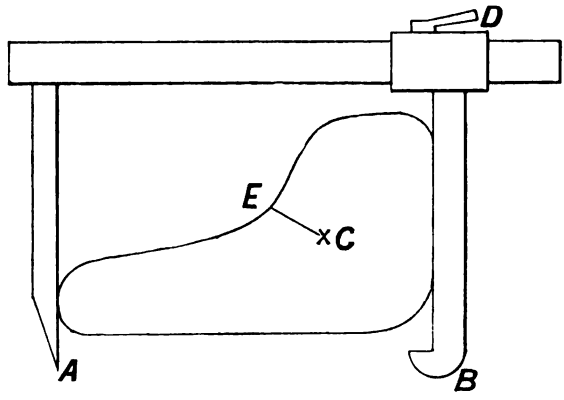


Then $x = 1$ (roughly) and

$$W = \frac{13{,}750}{400} \times \frac{p}{P_e} = \frac{34\ p}{P_e}$$

this of course makes no allowance for initial condensation; to cover all such loses, say $W = 50\ \frac{p}{P_e}$ This formula, which only professes to be of the roughest type, gives a very fair idea of the weight of steam an engine actually uses.

For getting the mean effective pressure (P_e) of indicator cards, Mr. Goodman recently patented an extremely simple form of planimeter, which gives the mean height of cards without any calculation, and far more quickly than the usual method. It had no recording wheel or other mechanism that could possibly get out of order.



The instrument is first set to the length of the card by sliding out the leg DB, it is then held vertically with the point A, and the hatchet B resting on the paper. A is placed at the point C and a dent made in the paper with B, the point A is then caused to traverse the curve *via* CE, and thence back to C. The hatchet has now taken up a new position, it is again pressed into the paper to form a dent, the distance between the two dents is the mean height of the card.

Mr. Jenkins used Rankine's formula for arriving at the weight of steam required per indicated horse-power per hour for various grades of expansion; the speaker had constructed a formula which appeared to him to be somewhat simpler and yet accurate.

Let r = the number of times the steam is expanded.

v_o = the number of cubic feet of steam per lb. at the initial pressure p_c.

v_1 = the volume swept through by the piston up to cut off, plus the clearance volume v_1.

p_1 = the absolute initial pressure.

p_b = the back pressure.

v_2 = the working volume of the cylinder.

$$C = \frac{\text{clearance volume}}{\text{working volume}}$$

Then

$$\left.\begin{array}{l}\text{Weight of steam required per I. H. P. per hour}\end{array}\right\} = \frac{13{,}750\,(1+c)\,v_2\,l}{r\,v_o\,[p_1\,\{v_1\,(1+\log_e r)-v_o\}-p_b\,l]}$$

The cards and results of the triple expansion engine, given by the author, were obtained from an electric lighting engine, built by Messrs. J. & H. MacLaren, of Leeds; the tests were carried out by Mr. Wilson Hartnell, M.I.C.E., and Prof. Goodman; the results are believed to be better than any that have previously been obtained from an engine in this country. The main results were as follows :—

Indicated horse-power	121·8
Brake horse-power	106·9
Revolutions per minute	121·6
Boiler pressure	157lbs. □ in.
Vacuum	28ins.
Feed water used per indicated horse-power per hour, including jackets	13·6lbs.
Feed water used per brake horse-power per hour	15·5lbs.
Steam used in jackets per indicated horse-power per hour	1·24lbs.
Steam used in jackets per brake horse-power per hour...	1·41lbs.
Coal burnt per indicated horse-power per hour	1·35lbs.
,, brake ,, ,,	1·53lbs.
Water evaporated per lb. of fuel from a mean temperature of 110·7 F.	10·11lbs.
Do. from and at 212° F....	11·34lbs.

The steam shown by the indicator cards in the three cylinders was respectively :—

	High Pressure.	Intermediate.	Low Pressure.
After cut-off	0·079 ...	0·090 ...	0·068lbs.
End of stroke	0·080 ...	0·092 ...	0·074lbs.

The weight of feed water used per stroke was 0·114lbs.

Mr. W. J. YARWOOD, referring to Mr. Brown's remarks, said that while quite agreeing with him as to the inadvisability of compounding *new* engines at less than 60lbs. pressure, and also recognizing the fact that the simple expansion engine ashore with early cut-off, say $\frac{2}{5}$ths stroke, had achieved astounding results, still the fact must not be overlooked that there were compound engines working at less than 60lbs., the results from which had shown that in converting from simple to compound, the right course had been adopted.

His firm, the Weaver Trustees, had a steam hopper barge and a dredger which were both fitted with vertical marine engines, two cylinders 18in. diameter, 20in. stroke, cut-off at $\frac{3}{4}$ stroke, boiler pressure 38lbs., revolutions 78, vacuum 24in., indicated horse-power 75, fuel consumption 6·75lbs. per indicated horse-power per hour.

A short time ago these engines were both compounded. In each case one 18in. cylinder was removed and a 30in. cylinder substituted. Steam was raised to 48lbs., this being the boiler limit, and the steam was cut off in both cylinders at $\frac{9}{16}$ stroke. The results were, revolutions 98, indicated horse-power 117 (and this easily maintained), fuel consumption 2·25lbs. per indicated horse-power per hour, showing a saving in fuel of 4½lbs. per indicated horse-power per hour, and an increase of power from 75 to 117. These engines in the first instance were not in a position to use steam as expansively as they might have done had they been fixed ashore and with an earlier cut-off.

He considered that the earliest cut-off which could be adopted with safety for compound marine engines, was $\frac{3}{16}$ stroke. If this was decreased there would be serious risk in the case of vessels trading on inland waterways, where there were locks and bridges to contend with, as, owing to the engines centreing and refusing to reverse at the last moment, there was liability of serious damage to lock-gates or turn-bridges. The two foregoing instances would, he thought, justify his view that there were special cases which would warrant the discarding of formulæ, and the following of compounding even at pressures less than 60lbs.

Mr. A. G. Brown, in replying to Mr. Yarwood, observed that what he intended to convey was that there was no economy in compounding a *good* simple engine at 50lbs. pressure. There were great differences in engines. He had tested a Corliss high-pressure engine, which developed a horse-power with less than 20lbs. of steam per hour, at 80lbs. pressure. This was a *good* simple non-condensing engine. He had also tested a compound condensing engine working with 120lbs. steam pressure, that required about 22½lbs. of steam per horse-power per hour. This was a *poor* compound engine, although not nearly so bad as some he had seen.

A *bad* engine, working with a low steam pressure, might be considerably improved by compounding, and then not be equal to a *good* simple engine. Another example was the Corliss compound engine at the Pawtucket Waterworks, made by Geo. H. Corliss himself; this engine developed a horse-power with less than 14lbs. of steam per hour, when working with 110 to 120lbs. pressure of steam. If this was compared with many of the compounds here it would appear to be an exceedingly good result, and one that would not be improved on by a triple engine at the same pressure of steam; but if the steam pressure was raised 40 or 50lbs. it was by no means certain that the comparison would be in favour of the compound, the chances being decidedly the other way. Therefore he asserted again that there was no economy in tripling or compounding at low pressures of steam.

The President (Mr. G. B. Goodfellow) in reviewing the discussion said many of his intended remarks had been anticipated and therefore they would be considerably shorter than he originally expected. To begin with, however, he thought Mr. Jenkins had not done justice to the compound engine in quoting an example of consumption of steam of 16lbs. per indicated horse-power per hour, and that he had given the triple expansion engine full benefit in stating its consumption of steam as low as 12lbs.

As regards the German tests he was of opinion that they were too good to be correct, if calculated on the same basis and made under the same conditions as we were accustomed to, it being rather peculiar that they were invariably under our best examples. He agreed with Mr. Rea in his desire that the steam engine

should be more studied as a heat engine than hitherto had been the case.

He was pleased to hear Mr. Hodgson's remarks about trippling at 100lbs. pressure, as it had been his experience for some time that triple expansion engines would work more economically at 100lbs. than the compound, for the simple reason that by trippling they were enabled to carry on the steam much further than when working with two cylinders.

As regards the assertion of Mr. Saxon that the engine should be proportioned to the load, he was of opinion that steam should not be cut off earlier than half-stroke in the high-pressure cylinder. Comparing the best types to-day of compound and triple expansion engines, he was under the impression that the amount of saving anticipated would not be confirmed by results in many cases. It was often expected that because they had obtained 50 per cent. more pressure with comparative little increase in heat a corresponding saving would accrue, but it seemed to be the general opinion of the speakers that the condensation with three cylinders and high pressure steam is much greater than at the lower pressure with two cylinders. Engineers had yet to learn a great deal as to how more effectually to use the higher pressures of steam, and this might account for some of the results not agreeing with anticipations. The condensation which took place in the cylinders could not all be re-evaporated because with the modern engine where the exhaust valves were at the bottom a great deal of the water left at the end of the expansion must get out immediately the exhaust valve opened, and would go forward into the pipes or receiver between the cylinders.

The proportions of cylinders in some old samples of early compounding, varying from 4 to 1 to as low as 2 to 1, as given by Mr. Jenkins, were quite correct, and he had known examples where the range in proportions had been much greater, and it was evident that some of the previous speakers, who had not come across these experiences, had got through the world with comparative ease. It was remarkable what good results were obtained with small high pressure cylinders, where the cut-off was very late. As pressures had increased the high pressure cylinders had been made larger in proportion to the low pressure;

he thought this a mistaken idea, because engine makers had been trying to get at a point of cut-off to suit the high pressure so as to have the return or back pressure as near as possible to the terminal pressure; by doing so it was necessary to cut off so early that more was lost by condensation than was gained by expansion. There were now engines working at 80lbs. pressure, with cylinders of 4 to 1, giving very economical results.

Respecting the commercial success of jacketting cylinders he was unable to come to a satisfactory conclusion, so many different results having been put forward, though at the same time it was certainly worthy of consideration by the Association. He did not think all the credit for the adoption of the triple expansion engine was due to the marine engineer, for many years ago there had been examples of both triple and quadruple expansion engines in this district. The saving on land of a small amount of coal was not of such importance as to make manufacturers at once incur large expenditure in new engines or alterations. However, he was glad to say, for the good of trade, that they were gradually becoming alive to the importance of a smaller coal consumption, and he did not think many new engines would be erected with any pretensions to being modern, with less than three cylinders for high pressures.

Mr. J. Higginson, Junr., said he should like to point out that no reference had been made to two very important causes of superiority of the triple over the compound engine. The first was that leakage past the valves and piston of the high pressure cylinder had very much less evil effect in the triple engine than in the compound engine, as the steam which leaked past had two more cylinders in which to exert its force, instead of one as in the compound. The second cause of superiority in the triple was that clearance which was unavoidable and which no amount of compression could completely remedy, caused much less loss of economy in the triple as the steam which filled the clearance space, or was condensed through the extra surface thus exposed, had two more cylinders in which to exert its force instead of one as in the compound. He should like to hear some opinions on these points as he thought they had an important bearing on the question.

Mr. JENKINS in replying said that he was very much obliged to the large number of gentlemen who had taken part in the discussion, for the contributions they had made towards a solution of the question brought forward in the opening statement, but could at the same time say that he expected, and hoped for, much more severe criticism than he got, because he had taken some pains to present the subject to them in a sufficiently unorthodox light to induce an opposition.

Only two or three gentlemen had followed the arguments and had made remarks directly bearing upon the question, but of course that did not reduce the value of what had been said during the discussion, though it did show that the latter wandered a little wide of the subject.

Mr. Saxon must notice that although a ratio of volumes of cylinders as low as 2 to 1 had been given in the paper it was not intended to convey the impression that that was the usual ratio for steam of 100lbs. pressure. That statement was given simply to show the direction in which progress had been made, and was not a definite statement. It would be very difficult to make a definite statement, since almost every engine builder of any repute had his own favourite ratio, and believed everybody else to be slightly wrong, although the results attained did not vary much with a considerable variation in the relative volumes. He quite agreed with Mr. Saxon that an engine was often too large for its work and that there was a limit to the amount of expansion which could be allowed in one cylinder. The effect of a very early cut-off would be to exceed the limiting range of temperature in the high pressure cylinder. In all probability the principal cause of the extensive use of the triple engine in marine practice was the necessity for reducing the heavy piston loads consequent upon the higher pressures at which the engines were worked; and the evenness of the turning effort upon the shaft, with the reduction of the stresses, were in themselves sufficient to justify shipbuilders introducing the system even if it had been found that there was no saving of coal.

Mr. Constantine was quite right when he pointed out that the fairest standard of heat economy of an engine was the number of units of heat utilized as compared with the total number supplied, but for most practical purposes the weight of steam

used in an engine, compared with a curve such as that on Plate I. was sufficiently proportional to the heat units, and was a much handier way of arriving at a result and carrying the same in the memory.

The commercial advantages of the triple expansion marine engine were undoubted, and since every ton of coal saved meant on board ship not only the money value of the coal, but also the money value of the extra space available for cargo, it was easy to see that there was a sort of double inducement to adopt small improvements on board ship. Mr. Constantine came very near the truth when he said that the very best compound was about equal to the ordinary triple engine.

Mr. Brown's contribution to the discussion was extremely interesting, especially when he said that the result of the trials of a simple engine using steam at 180lbs. pressure was that it worked most advantageously when cutting off at one-fifth of the stroke.

Referring to his remark that the work of driving the engine load from admission to cut-off was done in the boiler, Mr. Jenkins was quite prepared to agree with him that it ought to be so, as he had himself held that opinion up to a certain point, but he thought that there was ground for argument against accepting the idea in full. The temperatures 95° and 88° given in the paper were not intended to represent the higher and lower limits of the range of temperature in a cylinder; but 95° seemed to be the maximum, and 88° happened to be the range at which the best results he knew of were obtained.

Of course the result of all the interchanges and transmutations of heat in a steam cylinder was not to leave the cylinder dryer—that was not the contention at all—but if the action of the metallic walls alone was dealt with then they did tend to keep the cylinder dry.

Mr. Rea was quite right in pointing out that there was a tendency to get away from the question before the meeting, but not more so than must inevitably occur in all discussions of a wide subject.

Mr. Rea advocated a standard of economy based upon the heat units delivered to the engine: that part of his remarks was answered in connection with the answer to Mr. Constantine.

Mr. Boswell was an able and experienced advocate of the ability of boilermakers, and was quite right when he said that a boiler suitable for any desired pressure could have been made at any time during the past 20 years, providing the money to pay the cost was ready. After all, boiler making, like engine building, was a means of earning a living, and the boiler maker was not so ready at changing his standard of strength, because any new machinery he may require was of a heavy and costly character, depending much more upon the strength of his productions than upon the size. The engine builder on the other hand was readier at changing, because the operation of increased pressures was in the direction of making the individual parts of engines smaller and more convenient for his machinery for the same power.

Mr. Goodman's idea of jacketting cylinders with the waste gases from the boiler, and using scrapers to keep the surfaces free from non-conducting soot would undoubtedly pay for a trial. The idea of placing the cylinder in the smoke box of a portable engine was carried out many years ago by a Lincoln firm, and even before that by Mr. Allchin, of Northampton, upon a traction engine, which, by-the-bye, was also remarkable in being the first engine of the kind driven entirely by gearing, instead of a pitch chain, the latter method being universal up to that time.

Superheaters in the uptake were frequently tried years ago but the results were unreliable in one way or another. That economy could be gained by superheating there was no doubt. Mr. Jenkins's experience in a number of cases with small engines was, that so long as the firing was regularly attended to so that the chimney temperature was neither too high nor too low great saving resulted from the use of the superheater; but it was no uncommon thing to find the piston rod hot enough to char the packing in the stuffing-box, and the steam so hot as to burn the lubricant when anyone but a careful man had to do the firing. It seemed to him to be quite possible that the use of scrapers, as suggested by Mr. Goodman, may render the superheating surfaces so efficient and so regular in action, that they could be made so small that the greatest attainable uptake temperature would not in any particular case heat the steam to a detrimental degree. The famous Pawtucket pumping engine

in America had jackets heated by waste furnace gases, and in spite of repeated trials by different competent engineers, who did not believe in the economy of 13·6lbs. per indicated horse-power per hour claimed for it by the engineer in charge, it seemed to be a proved fact that such a high economy was reached. The pressure was about 110lbs., and the engine was a compound made by Corliss himself.

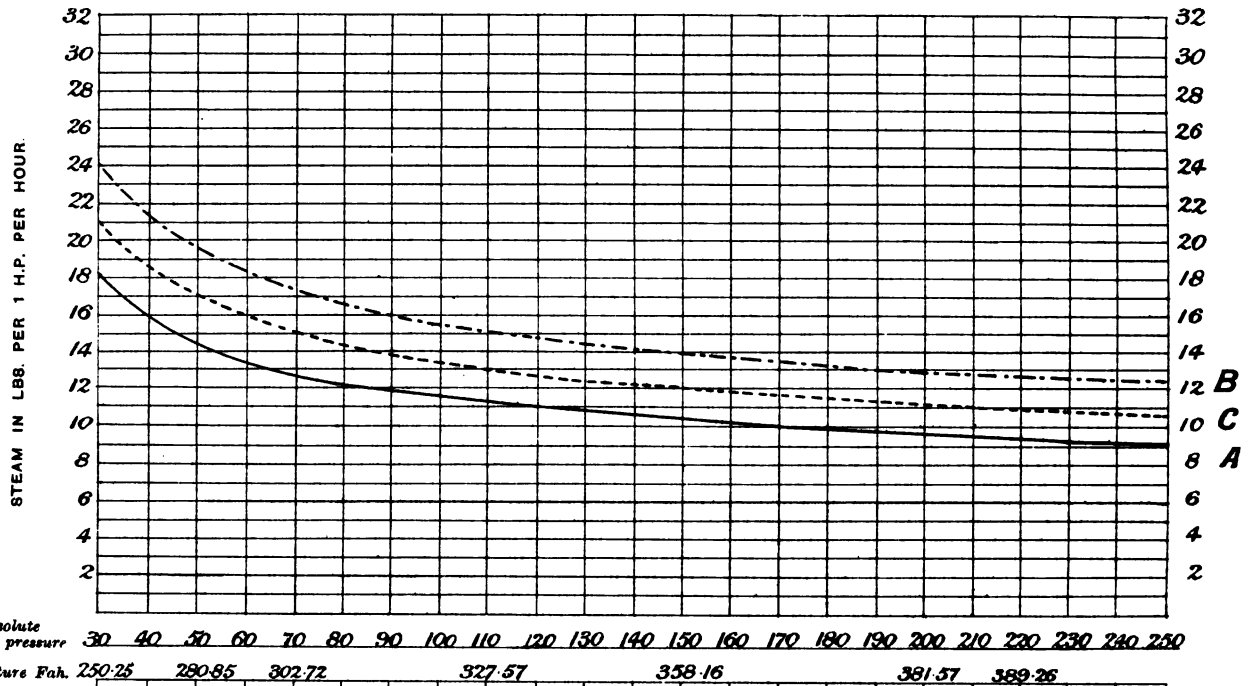
The President was doubtful of the accuracy of certain American and German engine tests; perhaps they used drier steam than we do in England, and that may account for the difference. The author had noticed that foreign boilers do appear to contain more heating surface exposed to steam alone than we consider good. Regarding the President's remark that much of the water due to initial condensation and work, may be blown out of a cylinder, having bottom exhaust ports, as soon as the exhaust valves open, and could not therefore re-evaporate, Mr. Jenkins would ask him how he accounted for the large quantity of heat left behind in the metal of the cylinder and not required to re-evaporate the water so blown away? He thought the President was wrong in supposing that any considerable quantity of water existed in a state to be blown out by steam, since the water surely existed not as a quantity distinct from the steam but mixed up and diffused as mist throughout the whole bulk of the steam.

On the motion of the PRESIDENT a very cordial vote of thanks was passed by acclamation to Mr. Jenkins, who suitably acknowledged the same, and the proceedings terminated.

DIAGRAMS.

UNIV. OF MICH.

DIAGRAM SHOWING MINIMUM WEIGHT OF STEAM REQUIRED PER HORSE POWER PER HOUR AT VARYING INITIAL PRESSURES WHEN EXPANDED TO A FINAL PRESSURE OF 6 LBS. ABSOLUTE, AND EXHAUSTING AT 8 LBS. PER SQUARE INCH.



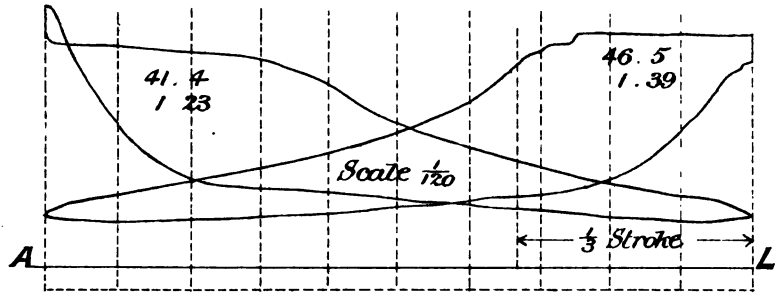
ABSOLUTE PRESSURE AND CORRESPONDING TEMPERATURES.

TRIPLE EXPANSION, COMPOUND, AND SIMPLE ENGINES.

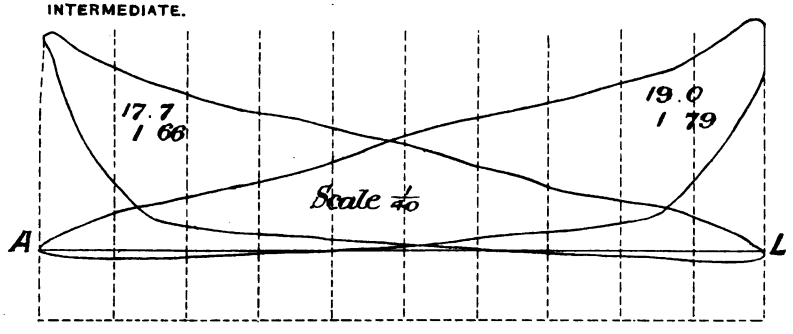
STEAM PRESSURE, 168 Lbs.

REVOLUTIONS, 122

HIGH PRESSURE.

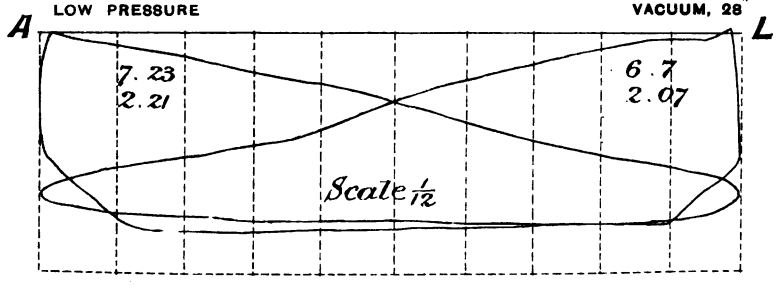


INTERMEDIATE.



LOW PRESSURE

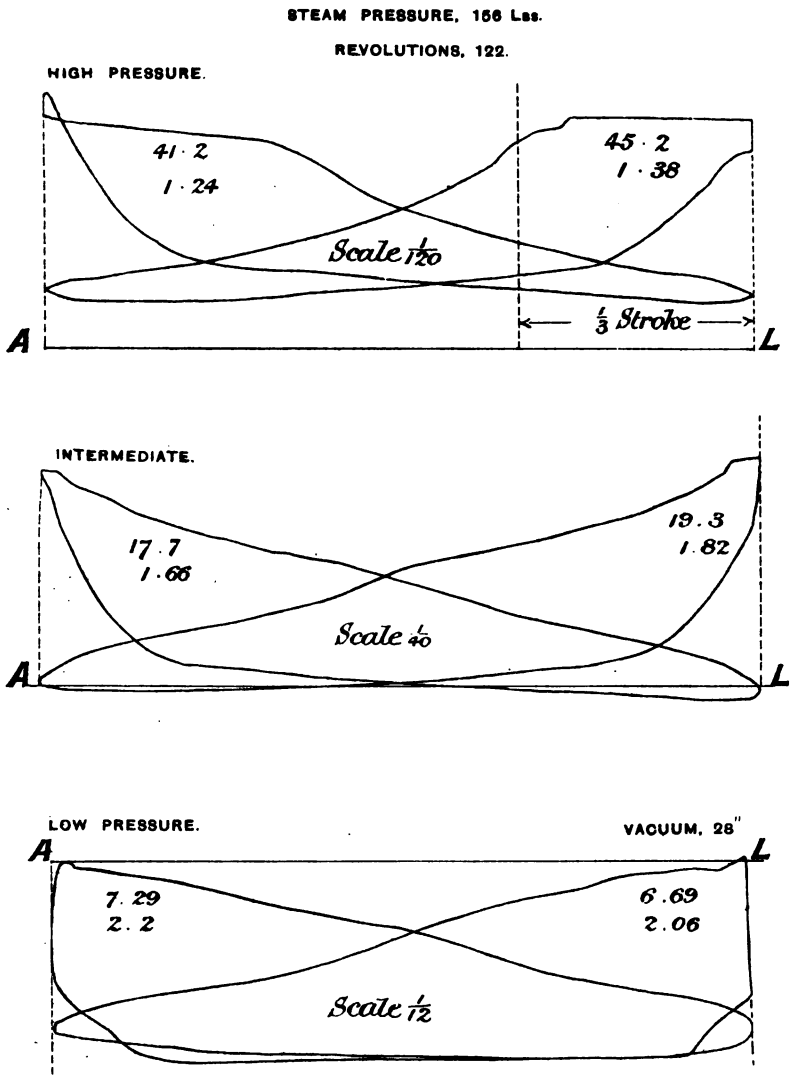
VACUUM, 28"



INDICATOR DIAGRAMS OF TRIPLE EXPANSION ENGINE.

UNIV OF MICH.

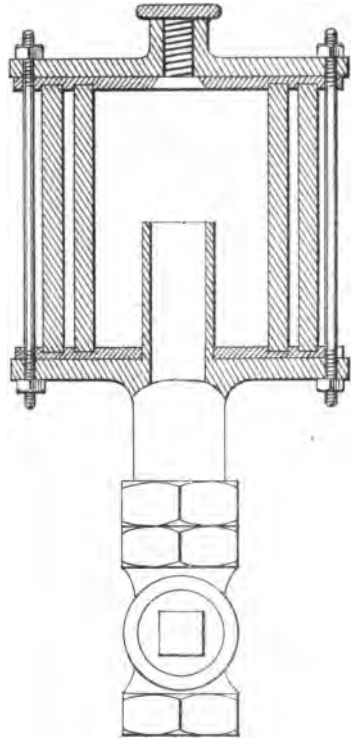
TRIPLE EXPANSION, COMPOUND, AND SIMPLE ENGINES.



INDICATOR DIAGRAMS OF TRIPLE EXPANSION ENGINE.

UNIV OF MICH

TRIPLE EXPANSION, COMPOUND, AND SIMPLE ENGINES



DONKIN'S REVEALER.

UNIV. OF MICH.

THE MANUFACTURE OF IRON,

BY

Mr. HENRY WEBB,

OF BURY,

READ SATURDAY, 27TH FEBRUARY, 1892.

INTRODUCTION.

Our ex-President (Mr. West) asked me to read a paper on Forgings, but I could not consent to do this as the subject seemed too "shoppy," and these meetings should not be used to serve private interests; but in a weak moment I consented to give some "Notes on the Manufacture of Iron."

Iron on account of its abundance, working qualities, and tenacity, is probably the most useful and valuable of metals. It is capable of being cast into moulds of any form, of being drawn into wire of any desired length and fineness, of being bent in every direction, of being sharpened or hardened, or softened at pleasure. Iron accommodates itself to all our wants and desires, and even to our caprices; it is equally serviceable to the arts, the sciences, to agriculture, and to war; the same ore furnishes the sword and the ploughshare, the scythe, the pruning hook, the needle, the graver, the spring of a watch or carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue, and the only metal friendly to the human frame. It is not only the soul of every other manufacture, but the mainspring of civilized society. Were the use of iron lost amongst us, we should in a few ages be unavoidably reduced to the wants and ignorance of savages.

It would be interesting to trace the manufacture of iron from the earliest ages. Frequent reference is made to this metal both in sacred and profane history, and a profitable evening could be spent in unravelling these references. It would be interesting to know the method of the manufacture of the iron in which Tubal Cain and his family were skilled artificers; it would be equally interesting to ascertain what kind of an iron bedstead Og, the giant King of Bashon, slept on; and it would

be most pleasing to inquire of what kind, and who made the iron mentioned by the Patriarch Job. But time will not permit us to examine into these things.

In order to connect modern practice with the earliest ages, I purpose calling your attention to two of the ancient methods of the manufacture of iron. 1. The Hindoo method, which has been practised for ages, and is still used in northern India, and was the pioneer of the modern blast furnace. 2. The Catalan process, which until the last few years was in active operation in the Pyrenees.

HINDOO METHOD.

The Hindoos appear to have carried on the direct process of iron smelting from time immemorial, as we may certainly infer from the large accumulations of slag which occur in various localities in India; and it is scarcely possible to imagine anything more rude than their appliances, or anything more diminutive than their scale of operation. Their furnaces are so small that hours of incessant toil are required to produce a few pounds weight of iron. The form of furnace generally used by the natives of Lower Bengal (see Plate 1) is built of the highly ferruginous sandy soil of the country, moistened and kneaded, and is generally strengthened by a sort of skeleton of strips of flexible wood. In form it is usually cylindrical, the walls being of either equal thickness throughout (about 3in.) or rather thicker towards the base. The height of the furnace is about 3ft., and the mean internal diameter about one foot, but the dimensions vary according to local custom. There are two apertures at the base of the furnace; one in front, about a foot in height and rather less in width than the internal diameter of the furnace, through which when the smelting of one charge is finished, the resulting mass of spongy iron is extracted, and which during smelting, is well plastered up, the small conical tuyere being inserted at the bottom. The tuyere is usually made of the same material as the furnace. The other aperture is smaller and placed at one side of the furnace and serves as a slag hole. The inclined tray at the back of the furnace is formed of the same material as the furnace; it is kneaded into shape, and supported on a bed of split bamboos laid on a wooden framework. On it is piled a supply of charcoal and ore, which

is raked into the furnace as required. The blowing apparatus is very ingenious. It consists of a circular segment of hard wood, rudely hollowed, and with a piece of buffalo hide with a small hole in the centre, tied over the top. Into this hole a string is passed, having a small piece of wood attached to the end to keep it inside the bellows, while the other end is attached to a bent bamboo firmly fixed into the ground close by. This bamboo acts as a spring, drawing up the string, and consequently the leather cover of the bellows to its utmost stretch, while air enters through the centre hole. When thus filled, the man places his heel on the hide, closing the centre hole, and drives the air out through a bamboo tube inserted in the side, and communicating with the furnace. At the same time he pulls down the bamboo with the arm at that side. Two such bellows are placed side by side, thin bamboo tubes lead to the same tuyere, and so by jumping on each bellows alternately, the workman keeps up nearly a continuous blast. The furnace is first dried by keeping a fire in it for some hours, it is then filled nearly half full of burning charcoal, after which it is filled to the top with charcoal and ore. The blast is then applied. When the charcoal sinks at the top of the furnace, alternate charges of ore and charcoal are supplied, until the proper charge of ore has been introduced, after which the blast is increased as much as possible and thus maintained until the close of the operation. Cinder soon appears in the hearth, and when it rises to the tuyere is tapped off by inserting a small bar through the slag hole. In from four to six hours a charge is completed, when, the front of the furnace being removed, a small mass of malleable iron, cinder, and unburnt charcoal is drawn out. If the operation has been properly conducted, the iron is sufficiently hot to be hammered into a tolerably sound bloom, with the exudation of a thick viscid cinder; but it is sometimes too cold for this purpose, and must in that case be reheated in an open charcoal fire. As a large part of the front of the furnace is removed at the end of each successive charge, in order to extract the iron, much time is lost and fuel wasted from the cooling of the furnace, hence it is impossible to work off more than two or at most three charges in one day. The yield is about 50 to 60lbs. per day.

CATALAN FORGE.

The chief modern representative of the bloomeries or hearths by which iron was produced from the earliest ages, down to the introduction of the blast furnace, is the Catalan Forge (Fig. 1, Plate 2), which until very recently existed both on the French and Spanish sides of the Pyrenees. A Catalan Forge consists of a furnace, a blowing machine, and a heavy hammer; and if the blowing machine called the "trompe" be employed, the forge should be erected in a locality where a fall of water from a considerable height, from 11 to 12ft. at least, may be secured. The furnace is usually contained within a building, and is always placed against one of the main walls, from which it is separated only by a little wall, and consists of a low hearth or open fire whose top is little higher than the floor of the smithy or forge. The hearth, about 30in. deep, is enclosed by four walls, that on the side of the tuyere, known as the "porges" is upright, and built of heavy blocks of cast iron; the opposite side called the "ore" is also of cast iron blocks, which are curved outwards, so that the breadth of the furnace increases from about 2ft. at the bottom to nearly 3ft. at the top. The third wall called "chio" is about 20in. high, also upright and of cast iron, and has a notch in it at the bottom for running out the slag. The fourth side, or "cave," is built of rough masonry with a slight upward batter. The hearth bottom is made of a block of sandstone, slightly hollowed at the top. The tuyere is made of sheet copper, it rests on the top of the "porges," and the angle can be varied with the requirements of the work, it usually being from 30 to 40 degrees.

In working the furnace the men first remove from the hearth the burning charcoal which it contains, and then carefully scrape off from the sides everything that may be adhering to them. They then throw burning charcoal into the hearth, which they subsequently fill up with this fuel to the level of the tuyere; the hearth is then divided, either by a shovel or by a piece of sheet iron into two compartments, parallel with the face of the "porges," in such a way that the space between the "porges" and the shovel may be twice as much as that between the shovel and the ore. Charcoal is now added in the larger space, and the opposite side is piled up with pieces of ore reduced to

the size of a walnut. The shovel is gently removed and the whole covered with charcoal dust and small ore (greillarde) moistened with water. At first only a gentle blast is used, and as soon as the flame appears at the surface it is damped by a fresh application of the "greillarde" in order to prevent too rapid combustion, and the falling in of the heap before the ore is reduced to a metallic state. The heap of broken ore is gradually roasted and reduced, the fuel is consumed and fresh charcoal added. The preliminary stage lasts about two hours, after which the blast is turned full on, and the slag tapped off. The workmen then push the heap of ore further into the fire by means of an iron bar introduced between it and the front wall. A spongy mass of iron forms at the bottom of the heap, which the men push forward towards the tuyere in order to facilitate the separation of the metal from the slag by the liquation of the latter. When the whole of the charge has been reduced, the blast is stopped, and the spongy mass in the hearth is worked together into a ball, which is lifted out and carried to the hammer. The heat lasts six hours. The iron is usually hard and steely. The average consumption of materials per 100lbs. of bar iron is, of ore 312lbs. (containing 45 to 48 per cent. of iron), and charcoal 340lbs. The yield per day is 600 to 700lbs.

TROMPE.

The Trompe or blowing machine used with the Catalan forge consists (see Fig. 2, Plate 2) of a large cistern, A, which is supplied with a constant stream of water, and connected with the box, C, by two wooden pipes, B, each about 20ft. in length. The lower box, C, which is firmly secured on all sides, and closely united to the pipes, B, is pierced with two openings, the one, D, near the bottom for the escape of the water, and the other in the lid, at E, through which the air escapes into the furnace through the tube, G, F, and the nozzle, T, which are connected by a leathern hose. The openings of the pipes, B, are at their point of junction with the reservoir partially closed by a sort of wooden funnel, which causes the water to descend in the middle portions of the upright pipes, instead of adhering to and running over their inner surfaces as it would otherwise be liable to do. A little beneath the openings of these funnels, small

openings, *g*, are cut in an inclined direction through each tube; these are called the "aspirateurs," and serve for the passage of the air drawn into the apparatus, by the downward motion of the stream of water. The two upright pipes, B, are firmly secured into the lid of the lower box, C, and are placed immediately over, and a short distance above a wooden shelf, on which the descending currents of water are, by their fall, broken into foam.

The action of the apparatus may be explained as follows: the water flowing from the upper basin, A, draws down with it a current of air, which enters through the holes, g in the vertical pipes, B, and passes into the lower cistern, C. The water which is broken by its fall on the bench below, escapes by the opening, D, whilst the air which has been drawn with it into the lower box, escapes by the aperture E. The position of the boards constituting the funnels is easily regulated by means of wedges, which allow of the descent of a larger or smaller supply of water, according to the requirements of the trompe. In order, during the working of the machine, to regulate the amount of air passing into the furnace at the different stages of the operation, each of the descending pipes is provided with a plug, suspended by a lever and an iron rod, by means of which the current of water, and consequently that of air, is readily controlled by the workmen. The air is delivered at a pressure of $1\frac{1}{2}$ to $2\frac{1}{4}$in. of mercury.

An elaborate description of this machine, also of the Catalan and other furnaces, and a scientific description of smelting ores by the direct process is to be found in "Metallurgy: Iron and Steel," by John Percy, M.D., F.R.S.

BLAST FURNACE AND ACCESSORIES.

From the Catalan Forge to the modern Blast Furnace is a long step, but it is not necessary, nor will I weary you, with the various improvements that led up to it.

From what has been said thus far you will note, that the only merchantable product in the early days was bar or malleable iron obtained direct from the ore; cast iron being a subsequent discovery, consequent upon the employment of larger furnaces and higher temperatures. In process of time, it was found that

the production of cast or pig metal, as an intermediate stage in the manufacture of malleable iron, was attended with advantages not possessed by the older methods, so that now it is followed exclusively by means of the Blast Furnace.

To describe accurately the Blast Furnace and its Accessories would require an evening of itself, and all I can attempt is the merest outline; to those who wish to pursue the subject I would recommend the book written by Sir Lowthian Bell in 1884.

When the Blast Furnace is at work it is kept filled to the top with fuel, ore, and flux, the latter being mixed in proper proportions. To produce the most fusible combinations of the earthy matters, a constant stream of air is maintained through the tuyeres, at a sufficient pressure to pass freely through the contents of the furnace. Part of the incandescent fuel subjected to the blast is completely consumed, burning to carbonic acid with a development of the maximum of heat, whereby the matters immediately adjacent are melted, and fall into the hearth, when they separate by liquation into metal and slag; the latter being specifically lighter, rises to the surface, and protects the former from the oxidizing action of the blast; the slag is tapped at regular intervals at the dam, and the metal at the tapping hole. Thus the solid contents of the furnace are gradually and uninterruptedly descending, and a current of atmospheric air from the tuyeres is continually ascending to the top, when it is carried away in pipes, or in some few cases allowed to escape. The carbonic acid formed in the first instance, encountering fresh fuel, is reduced to the state of carbonic oxide, a process which is attended with a great absorption of heat, so that the region in which a temperature sufficiently high for the fusion of metal and slag prevails, does not extend very far from the point of introduction of the air. (See Plate 8.) The carbonic oxide so produced, and the unaltered nitrogen of the air, when brought with oxide of iron ore at a red heat is again oxidised to carbonic acid with the simultaneous production of metallic iron, which becomes carburetted by further contact with carbonaceous matter in its descent to the hearth.

The alternate production of carbonic acid and carbonic oxide, by the reciprocal action of carbon and oxides upon the gases, is continued in the upper part of the furnace so long as the

temperature remains sufficiently high, the quantity of the former gas being augmented by the decomposition of the limestone flux used. Ultimately, however, a sufficient amount of carbonic oxide remains in the so-called waste gases, to form a valuable fuel, yielding sufficient heat, when collected and utilized, for all the accessory operations of the furnace.

From what has been stated you will note the fuel in the blast furnace is of a dual character; besides fusing it has to act chemically on the substances exposed to its influence. Again, ore requires a varying amount of heat, and consequently of fuel according to its content of iron, and demands for its treatment a larger or smaller furnace according to the readiness with which the mineral parts with its oxygen. One kind of ore like that of Cleveland, is most economically smelted by being exposed for a long time to the reducing influence of the gases, whereas other descriptions like the spathose ore, pass through the furnace in a very few hours. The atmospheric air varies in the quantity of moisture it contains. Mechanical difficulties are met with; owing to unequal driving and other causes scaffolding occurs, and the furnace should be of such a shape as to avoid this, and also to allow for the expansion of the charge. Care should also be taken to relieve the hearth from undue pressure.

The various problems which present themselves in the operation of the blast furnace are of the highest interest, and have taxed the skill of our best chemists and our cleverest mechanicians; into these I have neither the time nor ability to enter.

To give you a good example of a furnace see Plate 4, which is one of three erected in Newport in 1887, by Sir B. Samuelson.

The following condensed description and prices are from a paper published in the transactions of the Iron and Steel Institute in 1887.

"The furnaces are 85ft. high from hearth to platform level, with a bosh of 28ft., placed at an angle of 67°, well 8ft. diameter, and have a capacity of 30,000 cubic feet. The blast enters the furnace through six tuyeres at about 1,450° Fahr., and at a pressure varying from 4 to 5¾lbs. The diameter of the bell is 13ft. There are two Cowper hot blast regenerative stoves for

each furnace, each 23ft. diameter by 54ft. high to the springing of the dome. The blowing engines are four in number, having 78in. diameter blowing cylinders, and 40in. steam cylinders. This allows of having one off for repairs when necessary. They are of the vertical type and capable of blowing a pressure of 9 to 10lbs. per square inch. The boilers which also supply steam to the kiln and furnace, hoists, pumps, &c., are 14 in number, and are 5ft. 6in. in diameter, having a flue 2ft. 9in. in diameter. A combustion chamber is built at the front, where the waste gas from the blast furnace is admitted, and the flame after passing through the boiler flue, is divided, passing along a flue placed on each side of the boiler, and then enters a single flue at the front end running underneath the boiler, and so out to the chimney flue at the back. All steam is raised by surplus gas only.

The cost of this plant, erected in 1887, is as follows, viz. :—

	£	s.	d.
3 Blast furnaces	13111	11	3
2 Furnace galleries	996	2	6
2 „ hoists	1509	15	0
2 Hoist engines and houses	1776	15	10
6 Cowper stoves	9243	19	5
1 Chimney and flue for same	351	0	1
14 Boilers with setting and fittings..	7238	5	11
4 Seventy-eight inch blowing engines	5909	1	4
Blast engine house and tank	2136	19	7
Cold blast main and connections	484	19	9
Hot blast and horse-shoe mains	1377	19	4
Gas downcomers and flues	1505	17	4
Chimney for boilers	601	13	7
Force pumps, pipes, &c.	2648	17	11
5 Calcining kilns	3312	6	8
Bunkers, &c.	1934	7	7
Kiln lift	1478	11	0
„ gantry	1716	10	0
„ drop	698	18	5
Sundries, railways, &c.	6825	1	0
	64858	13	6
Shipping wharf and crane	1273	0	0
Slag wharf machines, trucks, &c., including two barges..	7373	1	8
	£73504	15	2

Contrast with the foregoing the celebrated furnace at the Edgar Thompson Works, Pittsburgh, America. (See Plate 5.) It was erected in 1886. The total height is 80ft.; the diameter of the hearth 11ft.; the diameter of the bosh 23ft. The bell is 12ft. diameter, and the stock line 16ft. The cubical capacity is 19,800ft. The bosh is protected by cooling plates inserted in the brickwork. The hearth is protected by water-cooled plates, which from their slanting position admit of a greater thickness of brickwork at the bottom. In the bosh are four rows of bronze cooling plates, eight plates forming the circle, and each plate having two water courses. In the two lower rows each plate is fed separately; in the upper rows two plates are connected together. Cast iron cooling plates are also placed between the tuyeres. (Nowhere in English practice have I seen these cooling plates.) There are seven tuyeres, each six inches in diameter. The volume of air blown is 27,000 cubic feet per minute, which is heated to an average temperature of 1,200°. The pressure at the tuyeres is 10lbs. The Americans use two blowing engines to each furnace, and three brick stoves, all other accessories being the same as our English practice.

It would be interesting to the members of this Association to compare the results of English and American practice, but this could not be efficiently done unless there was an exhaustive examination of all the varying conditions of each furnace, in each district under examination. Such a comparison would involve the most careful consideration of the richness of the ore, and its facility of reduction, (the richness involving the amount of material which has to pass through the furnace), the flux, the coke, the temperature, volume and pressure of air, the escaping gases, the slag and a host of other things, which would require minute investigation if a right conclusion is to be arrived at. In my present circumstances it is not possible for me to do this. It would also take too long to discuss the problem, as to how it is American furnaces produce five times as much iron as has been hitherto made in Cleveland from our poorer ore, and about twice as much as has been obtained from our hæmatite furnaces on the West Coast. Nevertheless, a general statement of what is being done in the various districts, and a broad comparison, may be useful to you.

CLEVELAND.

Cleveland practice on Cleveland ores averages 480 tons per week, or 25,000 tons per annum, with furnaces 27ft. diameter and 85ft. high, using 47·6 cwts. of ironstone and 10·4 of lime, making 58 cwts. for every ton of iron; the coke consumption being 19cwts. per ton of iron. A furnace will cast 350,000 tons before relining; but it is expected in some instances to make 475,000 to 500,000 tons pig iron from one burning in 12 years. The average Cleveland ore contains 30 per cent. of metallic iron. One firm in Cleveland is making as much as 700 to 900 tons Cleveland iron per furnace per week, but with what consumption of coke I am not able to state. In working on hæmatite ores containing 50 per cent. of metallic iron, in furnaces 20ft. diameter, and 84ft. high, the out-put is 800 to 1,000 tons per week in the best practice. The large furnaces where Cleveland iron is made, average 30,000 cubic feet capacity. The smaller furnaces where hæmatite iron is made, average 20,000 cubic feet capacity. They usually use six tuyeres, 6¼in. diameter at the nozzle, with 5½ to 7lbs. pressure of blast, the temperature of the blast 1,400° Fahr. Cleveland ore has 30 per cent. of iron, Hæmatite 50 per cent. Limestone is used as a flux, and Durham coke as fuel. It is worthy of note that one Cleveland furnace has run 19 years without relining.

CUMBERLAND.

In Cumberland the average capacity of furnaces to top of the stock line is 14,000 cubic feet. They use six tuyeres, 5in. diameter at the nozzle, pressure of blast 5lbs. per square inch, temperature 1,200° to 1,400° Fahr., as required, average analysis of ore 50 per cent. of metallic iron. The flux is limestone, 10 to 11cwts. per ton of iron produced. Coke 19¼ to 20½cwt. per ton of iron produced. (In this district they complain bitterly of the falling off of the quality of the coke.) The average make is 1,000 tons per week, and a furnace is good for five years without relining.

LANCASHIRE.

In Lancashire the capacity of furnaces average 20,000, cubic feet. They use six to eight tuyeres, with diameter at the nozzle 4in., pressure of blast 3¾ to 4lbs. per square inch, temperature 1,200° Fahr., average analysis of ore 50 per cent. of metallic

iron, limestone flux, and K.H. coke, using one ton of coke to one ton of iron produced; the average output is 650 tons per week, and the furnaces average five years before relining, but with special iron have lasted 13 years.

WALES.

In Wales they use seven tuyeres, 4½in. diameter at the nozzle, with a pressure of blast 4½lbs. per square inch. The temperature of the blast is 1,150° Fahr. The ore contains 49·2 per cent. of metallic iron. They use 8·22cwt. of flux per ton of iron, and average 21·27cwts. of coke per ton of iron. The best output is 910 tons per week, average 723 tons. A furnace will average 140,000 tons before relining is required,

LINCOLNSHIRE.

As an apt illustration of the difficulty of making comparisons no better could be found than the Lincolnshire practice. For example, at Frodingham the stone is found near the surface, from 18in. to 20ft. of sandy soil covers a layer of ironstone varying from 8 to 15ft. thick. This layer includes several lesser layers varying considerably both in formation and composition, from ferruginous soil containing 28 to 32 per cent. of iron, and 30 per cent. of silica, to a hard limey rock containing 11 per cent. of iron, and 40 to 50 per cent. of lime. This large variation in composition renders very careful selection and mixing necessary in order to get a fusible burden. Hence the flux used is the silicious ore of Mid-Lincoln and Northampton, the native stone being too limey. The peculiar nature of the stone necessitates a special method of charging. It is put into the furnace raw, through a tube 11ft. diameter, which is open at the top, and goes 8 to 12ft. down into the furnace throat, the gas being taken from around the outside of this tube by a large downcomer in the usual way. This mode of charging is also necessary owing to the excessive moisture (sometimes up to 30 per cent.) in the stone. The upper portion of the furnace containing the tube thus acts as a calciner. The furnaces are 12,700 cubic feet capacity. They have eight tuyeres, 3½ to 4in. diameter at the nozzle. The pressure of the blast is 2¾ to 3lbs. per square inch. The temperature is 1,300° Fahr. The output is 75 tons per day. Coke consumption 25½cwts. per ton of

iron. The ore averages 26 per cent. of metallic iron, and 73cwt. of stone are required per ton of iron. The furnaces are very variable as to duration before relining is required, but it is short compared with other districts.

SCOTLAND.

Here again there are very different conditions, many furnaces using 20 per cent. of coke and 80 per cent. of splint coal. The furnaces are 8,500 cubic capacity. There are 8 tuyeres 3¼in. diameter at the nozzle. The pressure of blast is 4 to 4½lbs. per square inch. Temperature of blast 1,200° to 1,300° Fahr. The ore contains 47½ per cent. of metallic iron, and requires 39cwts. of ore per ton of iron. The flux is limestone, requiring 6¼cwts. per ton of iron. If one cwt. of coke is equal to two cwts. of raw splint coal, the consumption is 38 to 40cwts. per ton of iron. The output is 360 tons per week, and the average life of a furnace is 100,000 tons, before relining is required.

AMERICA.

The *best* American practice with the No. 8 Edgar Thompson Furnace is 310 tons per day. The best output for any one week 2,462 tons. The monthly output is 8,000 tons. Average output of, say, 200,000 tons before relining. The coke 16·80cwts. per ton of iron. The ore is from Lake Superior, containing 63 per cent. of iron. The coke from Connisville. The average American practice is not so good as this. What is the explanation of this great output? The Americans have a good margin of profit, and an unlimited demand, hence the greatest quantity of iron is required in the least time. Then there is the stimulus to try and break the record. There is a wonderful spirit of emulation among the proprietors, the managers, and the men. It would be very interesting to discuss whether this great output is economical or not? Is it more desirable or more economical, to drive a blast furnace at a speed of 2,000 tons per week, the wear and tear and all things considered, than to obtain that production in two furnaces? These questions must be answered by those far better able to give an opinion than myself. Having seen these and other American furnaces, I must say I admire both the American plant and practice. They have had the run of England, and being a young country have

had our best practice to begin with, and on this they have improved, and it behoves us to see to it that we are not left behind in the race.

STOVES.

The subject of the blast furnace should not be left without some reference to one of its principal accessories, namely, the fire brick stove, by means of which the waste gases are burnt to the best advantage, the blast when passed through them is raised to 1,500° Fahr., a result which cannot possibly be obtained with the pipe stoves. The result is a larger production of iron and an economy in fuel.

Plates 6 and 7 illustrate the stove invented by Mr. E. A. Cowper, M.I.C.E., which was one of the first, and is still one of the best. It is worked intermittently on the Siemen's regenerative principle. The stove consists of a cylindrical tower with a domed top, B, 40 to 65ft. high, and 26 to 28ft. diameter, built of fire brick, with an iron casing, I. A tube or flame flue, F, placed eccentrically within the stove, extends from the bottom to the spring of the dome, while the remaining space being filled with fire bricks forms the regenerator, R. The bricks are carried upon grids, supported by girders, P, so as to have a clear space at the bottom, which is accessible by the manhole, M. The gas from the furnace, introduced by the gas valve, G, to the burners, N, is burnt by the air supplied through the air valve, A, forming a body of flame in F, which descends through the passages of the regenerator, and passes out by the chimney valve, V. The brickwork of the regenerator absorbs heat from the flame until it reaches a maximum temperature at the top, when the whole is visibly red-hot to within a few feet of the bottom. The gas is then shut off, and cold blast admitted by the valve, C, is passed through in the reverse direction, which becoming heated in its passage, cools the brickwork to a corresponding degree, and is delivered as hot blast by the valve H. When the brickwork is cooled below a red heat for about three quarters of its height, the blast is stopped and gas is turned on to reheat it, and so on. Two stoves at least are provided for each furnace, one of which is on gas, while the other is on blast. The regenerator is filled with Cowper's honeycomb bricks. These are hexagonal tubular bricks two inches thick, with radial span

at the angles, which when piled in the stove give a series of six sided flues, with walls uniformly two inches thick. The top course is made with sharp edges to check the lodging of any dust. The ordinary way of cleaning the stove from dust that may have hung against the sides of the passages is to fill it with blast at the maximum pressure, and suddenly to blow it out by opening the throttle valve, T, or by firing a gun in the space below the girders. When cold, the flues may be brushed down from above from the space under the dome, which is accessible from the gallery and cleaning doors at the top. The internal angles of the honeycomb bricks are rounded, affording a passage which is found to be less liable to choke from deposit than that formed of the thin bricks placed on edge, formerly used. There are several other very good stoves, Whitwell's, Massicks' and Crooke's, Ford and Moncur, and others, all giving excellent results, and each claiming special advantages, but into these I cannot enter.

Looking at the blast furnace plant and its accessories in the United Kingdom, and reviewing the practice as a whole, we may justly come to the following conclusions, viz. :—

1. That successful working is secured through the abundance and use of excellent fuel. Even in districts where fuel is inferior, by careful washing and coking in ovens of the most modern and economical design, fair results are obtained.

2. That the ores are for the most part easily smelted.

3. That generally the furnaces and plant have been renewed recently to bring them up to modern requirements.

4. That firebrick stoves are now generally adopted with excellent results, and that when cast iron heaters are still retained they are of modern type and large heating capacity.

5. That the height and capacity of blast furnaces is regulated by the nature of the materials with which it is fed. With good hard coke high furnaces are more economical, requiring less fuel with greater production. Where there is only soft coke or coal it is essential to have low furnaces.

6. That the pressure of blast must vary according to the work required. (In many cases increased blast has been tried, and although there was a slight gain in production there was a loss in fuel.)

7. The general opinion is in favour of a high temperature from 1,200° to 1,400° Fahr., and so far no economy has been found beyond this temperature.

8. The number and size of tuyeres depends upon the materials with which the furnace is fed. Coke (hard) fed furnaces have an average of 6 tuyeres, with nozzles 4½in. to 6in. In coal-fed furnace they have 7 to 9 tuyeres, with a smaller diameter at the nozzle.

9. That where firebrick stoves are used there is a saving of fuel, and an average increase of production of 10 per cent.

Into the question of the recovery of bye products I will not enter, although it is in successful operation in several places, and is becoming a very important feature in connection with iron smelting.

The iron from the blast furnace, in the most modern works, is tapped into a ladle, and taken direct to the Bessemer converter where it is made into steel, this is poured into ingot moulds; as soon as it is sufficiently solidified, the mould is stripped off, and the ingot put into the soaking pit, from which it is taken to the cogging mill, thence to the rail mill, and becomes a finished steel rail, cut to length, punched, and straightened, and all with the initial heat from the blast furnace. But I must refrain from speaking about steel as this paper has to do with iron only.

The iron from the blast furnace in the majority of cases is run on to the pig bed, and as soon as it is sufficiently cool to handle, is sent to its destination in the form of pig iron. Each time the furnace is tapped about 20 tons of metal is run on to the pig bed.

The pig iron is taken to the foundry, and after melting in the cupola is cast into any required form, or the pig iron is taken to the puddling furnace, and there converted into malleable or wrot iron.

PUDDLING.

The product of the blast furnace is cast iron (usually called pig iron), and to convert this into malleable (or wrot) iron, a reverberatory furnace is used and the process is called puddling. Briefly, this process consists in stirring about molten pig iron, on the bed of a reverberatory furnace, heated by a flame, until it becomes converted into malleable iron, through the decar-

burizing action of the oxygen of the air circulating through such a furnace. The general details of the construction of a puddling furnace are well known, and it is not necessary to describe them in detail; Plates 8 and 9 will give an idea of the construction; the principal thing requiring care is, the grate area compared with the size of the furnace.

The process of puddling is a very interesting metallurgical operation to watch, and may be described as including four distinct operations, viz.: (1) the smelting down of the charge; (2) its incorporation at a low heat with oxidizing fluxes; (3) the elimination of carbon by exposure to air at a high temperature; (4) the balling of the metal ready for hammering.

The working bed or hearth is usually covered with refractory slags rich in oxides of iron, about 1½in. thick, all the sides of the hearth are covered with tap cinder (called bull dog), and the whole plastered over with red hæmatite made into a paste with water, and afterwards rammed well in. A charge is 480lbs. of pig iron of various qualities, and about 100lbs. of hammer slag or iron scale; this is placed on the bottom of the hearth. All being carefully closed up, the damper and fire in full force, in about a quarter of an hour the metal begins to soften; the man puts in his "rabble" and turns each piece over so that the flame can play on all parts, and so prevent any sticking to the bottom of the hearth. The fire is then increased and the whole of the iron is melted, the puddler and his underhand now briskly stir the metal in all directions with the "rabble," the temperature being at the same time gradually lowered by the closing of the damper at the top of the stack, until the surface of the charge has a covering of slag, thus protecting it from further oxidation by the action of the air passing through the furnace. The fire is then made up and damper raised, the molten metal presents the appearance of boiling, and is swelling up and rising rapidly, jets of blue flame escaping everywhere from its surface, and the metal being spurted up with considerable force; this shows that the formation of carbonic oxide must take place deep below the surface, owing to the oxidation of the carbon in the metal by the oxygen of the oxidised products of iron with which the bottom and sides of the hearth is lined. The metal now soon "comes to nature," that is producing pasty

masses in the liquid cinder. The puddler at once fills his furnace full of smoky or reducing flame to prevent oxidation causing unnecessary waste, whilst he balls the iron together and as soon as possible brings each one out and takes it to the hammer; he usually has six balls, each weighing about 80lbs. The whole operation takes 1¼ to 1½ hours. The yield varies according to the quality of the pig iron, and the skill of the workman, but an average is 20cwts. of puddled bar from 22cwts. of pig iron consuming 25¼cwts. of best coal.

The ball is taken from the puddling furnace to the hammer, and made into a bloom, say about 5in. square and 2ft. long. This bloom is taken to the rolls, and by passing between suitable grooves is made into a bar, 3, 4, 5, or 6in. wide by $\frac{1}{16}$ of an inch thick; this is accomplished with the initial heat of the puddling furnace, and the result is called a puddled bar. (Some districts call it "muck" bar.) The quality will depend upon the kind of pig iron used, the kind of "fettling," the quality of the coal, and the skill of the workman. Instead of using a steam hammer some firms use what are called squeezers (see Plates 10 and 11), of which there are various modifications, the iron being squeezed into the form of a bloom instead of by the direct blow of the steam hammer. A puddled bar of the requisite width is cut cold at the shears to the required length, and then piled 4, 5, or 6 high according to the weight required, this being called a "pile." For example, a puddled bar 3in. wide, $\frac{1}{16}$ of an inch thick, cut to 19in. lengths, and piled 5 high, would be a suitable "pile" to roll into 1¼ diameter. A number of "piles" are put into a reverberatory furnace upon a sand bottom, and when at a welding heat are brought out and rolled through suitable grooves into any required shape, such as rounds, squares, flats, angles, &c., &c. This is the "crown" iron of commerce. The quality depends upon the mixture of pig iron used, and the care in manipulation. As to how the various firms make their best, best best, and other qualities, I ought not to state. Boiler plates are made from larger "piles," the top and bottom being one wide sound piece of bar, and the middle, of bars of various widths, so arranged as to cross the joints. Considerable thought and skill is required to make piles to roll into girders H Section, channels ⌴, Z iron, T iron, &c.,

otherwise in rolling they would tear, or prove unsound in working.

Some firms have no puddling furnaces and manufacture from scrap. Wrot scrap iron is purchased from engineers and machinists, and boiler makers, cut to length, cleaned from all dirt, rust, &c., and then piled on a wood board. In piling care should be taken to cross the joints as well as possible and make the pile solid. This pile is heated in a reverberatory furnace on a sand bottom, and when at welding heat is brought to the steam hammer and made into a bloom and rolled into a bar. This is cut up, piled, and reheated, as described in speaking of the puddled bar. This result is called a scrap bar, and is cleaner, tougher, and more reliable than iron made by the puddling process. Some firms, by repeated hammering, rolling, and reheating, make an exceedingly clean reliable scrap iron, suitable for screws, fluted rollers, pinion wheels and other purposes, where it is essential that only the very best quality should be used. Scrap iron is softer and more uniform in quality than puddled iron, the latter however carefully worked is often "steely."

FORGINGS.

In works where puddled iron only is made, forgings are made from this material. The puddled bars are cut to the length required and made into a pile (see Plate 12, Fig. 1). A general size of pile is 15 inches wide, 18 inches long, and 18 or 20 rows high, care being taken that a different width of bar is used in each row, so that all joints are crossed. Several such piles are put into the furnace, and when at a welding heat, are brought out singly to the steam hammer, and made into a slab (see Plate 12, Fig. 2). The dimensions of slabs vary according to the purposes for which they are required, an average size is 24 inches wide, 3 inches thick, and 36 inches long. To form say a shaft forging, as many of these slabs are put together as may be required for the purpose, say five or seven slabs; in this case the three middle slabs would have a V piece cut out and when slabs are placed thus on each other it is called a faggot. This faggot is placed in the furnace, and in doing so care should be taken that a space is

left between each slab; this is easily done by putting a few short pieces of iron between them, the object being to allow the flames to play freely between the slabs, so that the centres of the flat surfaces of the slabs may come to as good a welding heat as the outside edges; want of attention to this little detail is the cause of many defective welds. The porter bar or staff is put into the furnace along with the faggot; this staff is driven by a tup into the V place cut out of the slabs as described. Care should be taken that the staff is the right shape, and driven well in and firmly welded. The faggot and staff are then brought out of the furnace by means of a crane to the steam hammer and well worked. The mass of iron is heated again and again, and repeatedly forged, until it is sound and assumes the required shape and dimensions. If larger slabs are required and it is not convenient or desirable to make larger piles, several slabs are put together, say two, three or four; these are heated and forged under the hammer into a large slab. Several of these large slabs are put together to form a large faggot. This is called double faggotting. Some firms make slabs direct from the puddled ball, but this is not so good as from bars.

Other firms who use scrap only and have no puddling furnaces, roll wrought iron scrap bars, and pile and work them exactly the same way as has been just described for puddled bars. Forgings so made are very good, and much cleaner than if made of puddled iron, Most firms, however, buy wrought iron scrap, cut it to suitable lengths, have it carefully cleaned, all dirt and rust scoured off, and pile it upon a piece of wood. These piles should be carefully made, the pieces of scrap being well crossed and all spaces filled up with small scrap. The piles or scrap balls as they are sometimes called, are put into a furnace, and when at a welding heat are brought out singly to the steam hammer and thoroughly welded and forged into a slab (this is called "shingling.") The slabs are put together as a faggot and heated as before described, double faggotting being resorted to where necessary or desired. At all large forges a stock of slabs and blooms is usually kept on hand for cases of emergency. There is another method of making forgings which is very generally adopted, that is without putting the iron together as a faggot the object being to avoid any chance of the staff not

being welded to the faggot. A suitable porter bar or staff is selected according to the kind of forging required, and some slabs (say four) are put on the end to commence with (see Plate 13, Fig. 1), these are heated and welded under the hammer, the staff is then turned over and another lot of slabs are placed on the opposite side which are heated in the same way ; this process is continued until a large mass of iron is put together sufficient to round up sound, and forge into a shaft or any other forging. This method has always to be resorted to when the shaft is too long or too small in diameter to be forged from a single faggot. By both methods whether by faggot or laying up the staff, the object is to get a mass of sound iron together large enough to forge into the article required whether shaft, connecting rod, crosshead, &c., and this is done by repeated heating and hammering until it is perfectly sound and to the dimensions given.

It may be interesting to you as engineers to know how a large crank, such as a marine crank is forged. Usually these are too large to be made from one faggot, therefore a suitable staff is selected (see Plate 13, Fig. 1) and made large enough by the addition of a few slabs as before described. It is then flattened down to receive other slabs as shown (Plate 13, Fig. 2 & 3). After making this side sound it is turned over and the process repeated on the other side, and this is done again and again on alternate sides until there is sufficient iron to commence forming the crank web (Fig. 4). Before proceeding further the staff should be set down to one side (see Plate 14, Fig. 1), and balance weights put on the staff to enable the workmen to turn it easily, as without these this could not be done, the iron being on one side. If it is a large crank, too large to get the required width of web out of the slabs already put on, the forgeman now sets it down, or tapers it towards the part of the web where the crank pin will be and lays on side slabs (see Plate 14, Fig. 2). These slabs are broad and thin and should be as long as the web which is being laid up. The bottom edges of the slabs should be scarfed or thinned. After these are heated and welded a similar number are put on the other side, and this is repeated until there is enough iron together to form rather larger than the size of crank web required, and the grain of the iron runs in the direction of the dotted lines (Plate 14, Fig. 3). The whole is then heated and

the crowns of the web rounded up until it is something near the size of web required as regards depth and thickness, but considerably longer. Then by means of a steel cutter a piece is cut off the side nearest the staff which is dressed off quite square. (Plate 14, Fig. 4.) Then a triangular piece is cut out (see Plate 15, Fig. 1), this forms the other side of the web. The piece left is then hammered down to the rounded part or neck of the shaft; if there is not sufficient iron, this is scarfed down and more slabs laid on (Plate 15, Fig. 2), but it is better to avoid this if possible. Having rounded up the neck of the crank a lump or swell is left (Plate 15, Fig. 3), on to this half the collar is welded, the iron having been previously made to the size, and bent to the required radius and scarfed. The other half is then welded on (some firms put them on in three pieces), the whole is then made sound; this collar being very much wider than is required (Plate 15, Fig. 4). The inside of the collar is then cut off and neatly trimmed to the required length and size (Plate 16, Fig. 1). The outside is then marked off and cut down with a cutter so as to be more easily cut off after the forging is finished (Plate 16, Fig. 2); the remainder is hammered out to form a temporary staff by which to hold and work the crank whilst the other end is being finished. One half, or perhaps better than the half, of the crank shaft forging may be said to be complete. It is now turned end for end, and the original staff put through the furnace until it is hot enough to cut off. After this is done, if a collar is required, one is welded on exactly as previously described with the exception that the outside of the collar is now cut square down. The staff drawn on the end of the first collar for the convenience of handling is now cut off, and we have the crank shaft forging complete as shown (Plate 16, Fig. 3).

From what has been said as to the method of forging you will be better able to judge as to whether little flaws or marks, and little longitudinal seams which are sometimes seen are of serious moment or not, sufficient to condemn the forging. In the majority of cases they are of no practical importance, and if discovered before a large and expensive forging has gone too far it would be better to place the forging in a smith's fire, have the mark opened out, and any little dirt or slag, or other impurity there may be taken out, and the iron then thoroughly

welded up again; this might be done and you would have confidence that the shaft was sound. This is a paper on iron therefore I must refrain from saying anything about forging steel. A forge requires good furnaces, strong cranes, double acting steam hammers, many miscellaneous tools, and skilled steady workmen. The furnaces are usually the reverberatory type with open grate, and with closed grates and steam jets, or the regenerative gas fired furnaces. The old fashioned reverberatory open grate furnace is as efficient and economical as any, given a good furnaceman who knows how to keep the bottom and neck of his furnace the right shape, and how to fire. Cranes cannot be too strong to resist the constant jar and shake of the hammer.

The hammer should be a quick-striking, double-acting steam hammer, able to "strike while the iron is hot," and for this purpose should not be worked at too low a pressure. The steam is raised by the waste heat from the reverberatory furnaces; if gas-fired furnaces are used, auxiliary boilers are needed for steam purposes.

STAMPING.

It would be difficult to define precisely, which operations in the blacksmith's forge, are comprehended under the general term of stamping. But it is generally understood to mean hammering between dies or moulds, and the tool commonly used is known as a drop hammer. (See Plate 17.) The operation of forging between dies has become of very great importance in modern iron manufacture, and is largely practised in Birmingham and Leeds, by the agricultural machine makers of the midland counties, by a few of our leading machinists in this district. There is a very complete installation of tools for this purpose at the Enfield factory for the manufacture of parts of the ordnance required by our army and navy. In America the firm of Billings and Spencer of Hartford, and J. H. Williams and Co., of Brooklyn, are justly celebrated, having large establishments to make stamped forgings for the trade. The stamping machine replaces the labour of smithing, which is essentially manual, and depends upon very considerable skill on the part of the workman; it is therefore very economical in its results, wherever it can be introduced. The chief condition for the economical introduction

of the process of stamping into any manufacture, is the demand for a great number of articles to be produced from one and the same die, so that the expense of producing the dies, which as a rule, are very costly, may be but a small item in the total cost of production. Generally speaking it will not pay to make dies for a less number than 500 forgings. The dies should be made of mild steel and then hardened for the large forgings, and of best cast steel for the small forgings. They should be made so as to release the finished article with the utmost facility. This to some extent depends upon the shape of the article, and should always form a consideration in the design of the article itself; but, with a given shape, it then depends upon the method of dividing the labour upon the number of dies employed successively (as it can seldom be done in one die), and upon the proper removal of all surplus metal. Generally in making articles of intricate shape two or three moulds (or dies) are used in succession, each bringing the material somewhat nearer to its ultimate shape. All "fins" formed by the surplus metal should be carefully removed, which would interfere with the action of the following dies. In the manufacture of some difficult forms of stamped forgings, I have known them to have to pass through five or six successive stamping operations before they are finished. To decide how many moulds an article is to pass in succession, is a matter of practical judgment rather than of scientific reasoning. There must be ample opportunity given to the metal to accommodate itself to the shape into which it is to be brought; the action of the dies, should be, as far as practicable, uniform over the whole mass, and the displacement of material as nearly as possible equalized. Abrupt corners and bends should be avoided, and should not exceed the size which the quality of the iron or steel under treatment is known to allow.

Most here are doubtless familiar with the investigations of the late Mons. Tresca, on what he called the "flow of solids." I well remember hearing an interesting discussion on this subject arising out of a paper read by the late Mr. Daniel Adamson at Paris in 1878. Mons. Tresca spoke eloquently on this subject, which at that time was new to many who heard him. His theory is a great help in studying the action of dies, viz.: by observations upon the changes in form which a pile of lead plates will

undergo when exposed to their action. The alterations of the superposed layers of lead, when brought between the dies, indicate the nature of the movements which take place throughout the mass operated upon, and point out the places in which to ease the exit of the material, and those in which the pressure is applied to most advantage. Such means for assisting the judgment in the shaping of dies for stamping is of the utmost importance and value, their absence having caused many a failure and thrown many a useful invention into disuse, where success might have been obtained.

Forgings made by means of the drop hammer are too numerous to mention, but such as keys, parts of locks, parts of sewing and other small machines, parts of power looms and spinning machinery, small arms, single and double wrenches, lathe dogs, thumb-nuts, thumb-screws, pipe cutters, bushes, cramps, connecting rods, cranks, &c., &c.

Amongst the most successful methods of making *large* forgings on this principle is that of M. Arbel. (See Plate 18.) He confined his attention almost exclusively to the manufacture of wrought iron railway wheels. He constructs a pair of dies to enclose the whole wheel complete; he piles up the wheel from numerous pieces hammered and stamped to the required shape beforehand, and he then adjusts all these pieces (which form his pile, and are heated in a furnace to a welding heat) to fit into the lower mould upon his anvil. The upper mould is then brought down with the hammer head, and the wheel is finished by repeated blows. This process has been worked for many years in France with great success. M. Arbel manufactures railway wheels of all dimensions, including locomotive driving wheels up to eight feet diameter by this process, and the solidity of the welds as well as the fine appearance of these forgings leave nothing to be desired. I believe wheels were made by a similar method to this for many years at Rotherham. But these will now be superseded by steel castings with a steel weldless tyre shrunk on to the rim.

In the Manchester district each engineer, toolmaker, machinist, &c., clings to his own special design, even in small things, whereas if there were uniformity, many of the smaller forgings could be made by the drop stamp exact to size and shape, and at much less cost.

HYDRAULIC FORGING.

In speaking of forgings you will naturally expect me to say something about hydraulic forging presses, as these have come more into use of late years.

The first hydraulic press for forging that I have either read or heard of, is the one patented by Sir Charles Fox, of the late firm of Fox & Henderson in 1847; it was used for making spokes, axle guards, heavy links, &c. The next patentees of presses for forging are Mr. Dubs (now of Glasgow) in 1853, and Mr. Bessemer in 1860. Mr. Haswell of Vienna, patented a forging press in 1861 (see Plate 19), which caused a considerable amount of interest in this country; one was made by the Kirkstall Forge Company of Leeds, for the Cyclops Steelworks, Sheffield, and great things were expected of it.

In September, 1876, a paper on the Haswell press was read at the meetings of the Iron and Steel Institute, and an interesting discussion ensued. Several splendid specimens of the work done by this press were exhibited, such as a section of a 12 spoked wrot iron locomotive wheel, showing three spokes with their portion of rim and boss pressed out of the solid slab. Also locomotive crossheads, double crossheads, outside crank and and its pin, piston rod socket, locomotive axle box, were shown, all of which created considerable sensation, and it was expected a new era of forging was upon us. Presses of a similar kind at this time were reported as being successfully used at Herr Borsig's works in Berlin, at Herr Krupp's at Essen, and by Mr. Wm. Sellers at Philadelphia. These were followed by the presses designed by Messrs. Shanks & Kohn, and made by Messrs. Platt Brothers of Oldham. (See Plate 20.) All the forenamed presses were designed and intended for squeezing articles of iron, or of mild steel, into moulds, and thereby producing forgings of an irregular or intricate shape at less expense, and with less trouble, than is attendent upon forging by the steam hammer, and with smiths. As far as my limited experience goes they have been failures; most of the presses were not heavy enough or strong enough for their work. A pressure of at least 10 tons to the square inch is necessary for an hydraulic forging machine with closed dies, especially if the mould has any sharp corners. The dies are

very expensive, and duplicate work can not be procured in sufficient quantity to make it pay. At the present time good sound reliable steel castings can be made so successfully as to hinder further efforts, or investment of capital in this direction.

We all know how successful the late Sir Joseph Whitworth has been with his press, it having been in constant use ever since it was first made (see Plate 21), but this press was designed for a different purpose to those just mentioned. He subjected steel to a high pressure *during casting*, to such a degree that a column of metal was diminished one-eighth of its whole length in less than five minutes, the pressure used being nine tons to the square inch. The object is to make sound castings, and to do away with the necessity for great "heads" of metal. It has been a dangerous and difficult process to carry out but is now used daily. One important thing to note is, that in subjecting *fluid* steel to very high degrees of pressure in steel moulds, and at the same time cooling it in them, the amount of the pressure applied should always exceed that produced by the shrinking or cooling which is simultaneously going on; or in other words, the pressure applied should be sufficient to overcome the counteracting forces resulting from the rapid cooling of the surfaces of the article, and the slower cooling of the interior metal, so that the atoms are caused to approach each other by the pressure, more rapidly than the said counteracting forces can separate them. But to-day, when hydraulic forging is mentioned, our thoughts at once turn to the powerful presses used by such firms as Sir Joseph Whitworth, Lord Armstrong and several firms in Sheffield and in Leeds for forging large masses of steel into guns, gun linings, marine and other shafting, &c.

In the production of heavy forgings from cast ingots of mild steel, it is essential that the mass of metal should be operated upon as equally as possible throughout its entire thickness. When employing a steam hammer for this purpose, it has been found that the external surface of the ingot absorbs a large proportion of the sudden impact of the blow, and that a comparatively small effect only is produced on the central portions of the ingot, owing to the resistance offered by the "vis inertia" of the mass to the rapid motion of the falling hammer. This is overcome by the slower, but more powerful compression of the

hydraulic forging press, which in the future will supersede the steam hammer for the production of massive steel forgings. It is more compact, occupies far less space, requires less foundations, and being self-contained the work is more evenly distributed.

Plate 22 represents an hydraulic forging press at work at Messrs. Bessemer Limited, Sheffield. The principal merit claimed is, that the force pump and the main cylinder of the press are in constant and direct communication. There are no intermediate valves of any kind, nor has the pump any clack valves, but it simply forces its cylinder full of water direct into the cylinder of the press, and receives the same water, as it were, back again on the return stroke. Thus, when both cylinders and the pipe connecting them are full, the large ram of the press rises and falls simultaneously with each stroke of the pump, keeping up a continuous oscillating motion. The ascending motion of the ram is effected by means of the steam cylinder, which on the return stroke raises the ram, and forces the water back on to the pump plungers as they recede from each other. The press ram makes a stroke of 2⅞in., and its diameter is 30in., so that with a pressure of three tons to the square inch there is a power of 1,700 tons. Why two such different forces as water and steam should be used in the same press I cannot understand? It seems to have several objectionable features. A paper on this press, by Mr. W. D. Allen, was read at the 1891 September meeting of the Iron and Steel Institute, but there was no discussion whatever.

Plate 23 represents a large hydraulic forging press, constructed by Messrs. Davey Brothers of Sheffield. It has two 36in. pressing rams, A, and two 9in. lifting rams, B, having a common stroke of 7ft., whose cylinders are carried by four columns on a heavy entablature, C, of cast steel. The four rams are connected with the toolholder or crosshead, D, carrying the forging tool corresponding to the tup of a steam hammer, which is guided in its course by side blocks fitting the columns, E; but the connections are not rigid, spherical bearings being substituted in order to allow for the expansion of the crosshead by heat, when the press is at work. The hydraulic power is supplied by three 6in. single acting rams driven by two 34in. steam engines.

Their capacity is such that the crosshead is depressed half an inch for each revolution of the engines; the lifter is raised 8in. at each revolution. The lifting and lowering of the tool when not in contact with the forging on the anvil is performed by water at 60lbs. pressure per square inch, supplied by the pipe, F. The forging pressure is obtained by the pumps which supply the large rams with water at any pressure up to 4,800lbs. per square inch, by the pipe, G, the maximum effort being computed at 4,000 tons. The pumps may be worked up to 60 strokes per minute, thus the press is nearly as quick in action as a steam hammer. The anvil and columns are carried on cast steel girders, H, somewhat similar to the entablature but heavier, which rest upon masonry foundations of considerable thickness.

Other forging presses vary from the foregoing in only having one large pressing ram, and the lifting and lowering of the tool effected by mechanical means, and other minor differences. In all cases they work direct from the pumps, and the pressure varies from half a ton to the square inch for a light short squeeze, to 2½ tons to the square inch for a heavy squeeze, the length of stroke can be regulated quickly and to the greatest nicety; they can be worked up to 40 strokes per minute, and with unerring certainty each time, so there is no difficulty in making forgings exact to size and quite straight, the press continuing each stroke exactly the same, unless the pressure is altered. Large pumps and accumulator are required to work the hydraulic crane, and various appliances connected with the working of the press. To watch one of these presses at work is far more marvellous than anything told in the "Arabian Nights." You stand by the press, and presently the top part of the anvil block, weighing many tons, silently glides away! You look for the motive power, and notice a youth has moved the lever of the valve of an hydraulic ram connected with the anvil. The chain of an hydraulic crane now quickly descends, and is being fastened to the tool which requires changing, this is readily done, and the block as silently glides back to its place! Your attention is now turned to a large mass of steel protruding from the furnace, it is a steel ingot 5ft. in diameter weighing 60 tons. Around the centre of this, and supporting it, is a massive flat endless chain attached to the blocks of a 100 ton overhead travelling

crane. Presently the large door of the furnace is lifted by hydraulic means, and you seem to look into "inferno," but the great glare and intense heat make you stand at a respectful distance. The ingot nicely balanced on the endless chain of the crane, is automatically brought out and placed on the anvil of the press, more than one half of the ingot being one uniform bright red glow. What a monster it looks! It does not seem possible to make it into any definite shape! But the press ram descends, and you hold your breath, whilst it quietly buries its face 6 to 9in. in the hot ingot!! By a very simple arrangement the endless chain turns the ingot round, and the press ram again descends with the same effect!!! This is repeated, until the whole red mass of steel is reduced 36in. or so in diameter, with a corresponding increase in length, and the ingot requires reheating. How beautifully simple! This large mass of hot steel is moved backwards or forwards any distance, turned round slowly or quickly, as desired, with the greatest ease. All automatically done! The hardest work is pushing a lever which opens the valve to send forth the powerful *geneii* to do your bidding. How different to the army of men formerly required at the end of the porter staff, and the tugging, and pulling, and levering to pull and turn a very very much smaller piece!! And yet this is only by using one of the commonest gifts of the Almighty, namely, Water. The "Giver of all Good" by the unfolding of nature and nature's laws, has still untold benefits to confer on the human race. The engineer is the means by which this will be accomplished, and it is the work of Associations such as ours, to meet for the interchange of ideas, for mutual conference and help, and a better understanding of those laws which shall confer untold blessings on generations yet unborn.

DISCUSSION.

The President (Mr. G. B. Goodfellow) expressed his appreciation of the value of the paper, and remarked that although perhaps there was little room for discussion upon it yet he should be glad to hear any questions upon the subject.

Mr. E. G. Constantine observed that he had had the pleasure of seeing some of the processes described, and he had been much impressed by that of making the rails in one heat. It might be interesting to some of the members, he thought, if the author would inform them of the difference in the boiler practice of 'mills and ironworks.' Once he inspected some egg-ended boilers, 65ft. long, at an ironworks, but it appeared as if the Lancashire type of boiler was being more adopted in ironworks than hitherto. Although these boilers were gas-fired, yet if lined with brickwork in the mouths of the furnaces, they seemed to give as good results as the egg-ended type of boiler. He should like to ask the author what had been his experience respecting puddling furnaces, and also if he were aware if anything had been done to cause more perfect combustion of fuel for the prevention of smoke.

Mr. Hans Renold was pleased to hear the remarks about stamping, as he was of opinion that it was a process not taken as much advantage of as was desirable. He thought that if a number of our tool-making firms would sink their individual crotchets and adopt a general standard for many of their machine details, such as screw keys, box keys, wrenches, single-ended crank handles, etc., etc., it would then be possible for a firm to take up this stamping speciality with a profit to itself, and a great advantage to the general machine making trade.

This was no untried prophecy, because on his last American journey he had many proofs that a more systematic and much greater division of the work had become an absolute necessity in the present days of keen competition.

It might seem strange, but in his own work he had found it greatly to his advantage to procure some of these American steel stampings for keys, &c., and although a somewhat heavy carriage had to be paid he could get, at lower prices, the best designed article, and well adapted for their purpose.

He was glad to hear the allusion made by the author to the marvellous work done by hydraulic forging presses. He would like to add that recently, while in Germany, he visited a place employing upwards of 3,000 men, women and boys, occupied in in the process of stamping and pressing metal in the cold state, which was carried to its highest perfection. This branch of manufacture was based on the fact that cold metal, Bessemer as well as cast tool steel, could be made to flow as desired, provided the pressure applied was great enough and did not move too rapidly; and when the metal became strained or fatigued it was restored by annealing before it was made to flow again. For the greater pressure nothing but hydraulic power was used.

One of the most marvellous things he had seen in this line was the making of 10ft. long tubes, 1¼in. outside diameter, out of blank discs from 10 to 12in. diameter.

He was of opinion that this also was a subject which ought to receive much more attention by the members of the Association.

Mr. JOHN WEST (Ex-President) remarked that he was much impressed with the fact of the Americans always taking care to have sufficient boiler and engine power, which he thought was not a prominent feature in English practice. The transatlantic people seemed to steal a march upon the English in that respect, as they appeared to always have surplus power in case it were required.

The author had referred to the recovery of chemical products from the blast furnaces, but of course for a long time that had been an important feature in the manufacture of gas.

The President (Mr. G. B. GOODFELLOW) agreed with the author respecting the bad effects accruing from the mixing of steel and iron scrap, and said that every effort should be made to keep the two metals separate in order to avoid

subsequent difficulty. The process of stamping was undoubtedly an important one, and one that should be more used. At the same time however, it must be borne in mind that the engine maker was not alone to blame, inasmuch as he had to comply with the requirements of his customers.

Undoubtedly the hydraulic press was a wonderful advancement on the steam hammer, and he could only think that the reason of its not being more widely adopted was that forgemasters like engine makers did not want to increase or change their plant till absolutely necessary.

Mr. SAMUEL BOSWELL said he would like to know the cause of blistering in iron plates, because he was of opinion that this defect had been the principal reason for the adoption of steel plates for the construction of boilers. He admitted that a blister about 6in. by 6in. in a furnace was not of much consequence, because he did not believe the plate was any the worse for it, unless it might have a trace of corrosion. In such instances the defect was so local that the strength of the furnaces could hardly be affected. It was a defect that except by an elaborate system of testing there was hardly any means of detecting, or until the boiler had been working for a time.

Mr. EDWARD J. LOWE asked in connection with the injurious effects of mixing steel and iron scrap if malleable iron were equally injurious?

Mr. WEBB in replying to Mr. Constantine said he did not object to a little smoke, and he thought if they had a few more chimneys sending out smoke instead of so many being idle it would show a better state of trade. However to prevent smoke from puddling furnaces, a good plan was to put across the roof of the fire grate a box with an opening say four inches wide and a wing valve in it. If the valve was opened when firing, and left open for a few minutes, little or no smoke would be seen.

The process alluded to by Mr. Renold was extremely interesting, but it was not stamping, it was the system of cold drawing, which was used in England and all other countries, notably in the manufacture of wire.

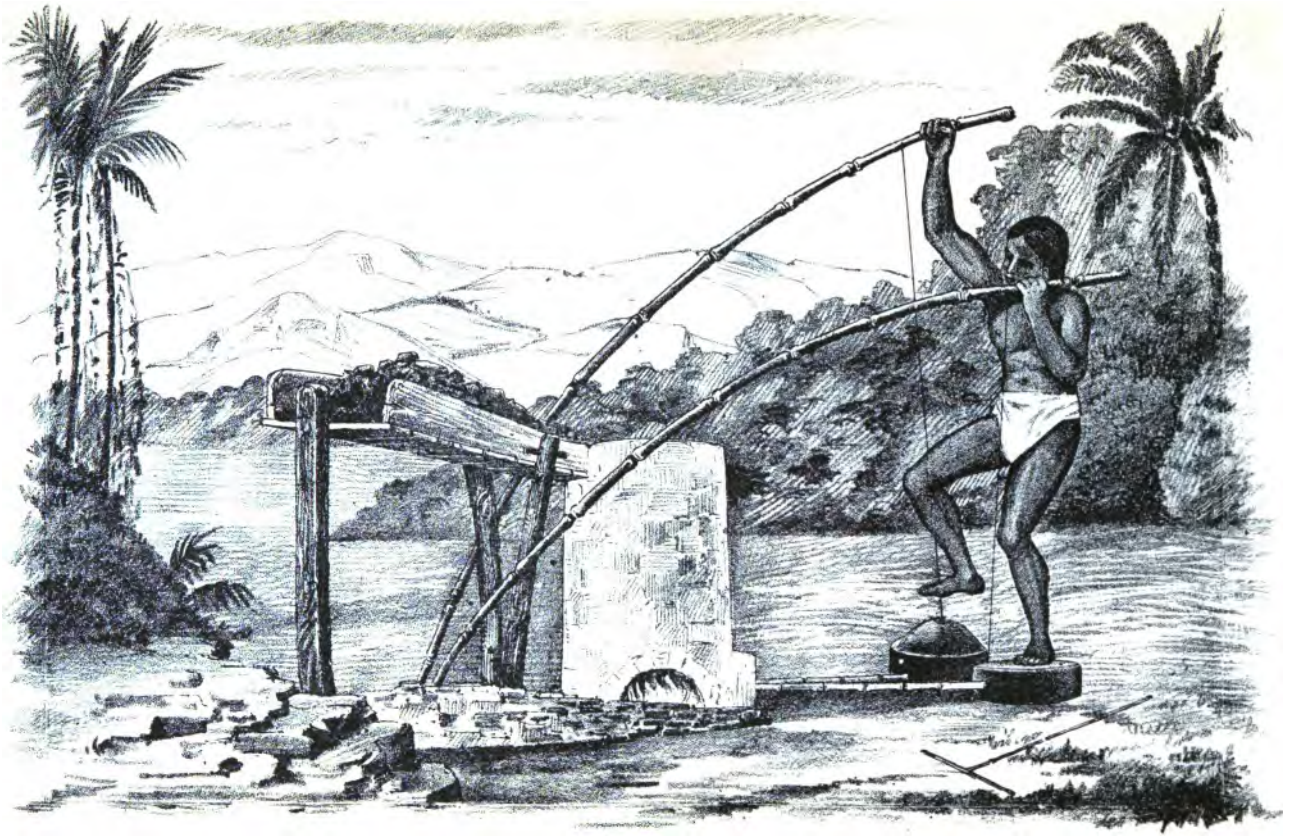
As to blistering in iron plates there were a variety of causes, such as imperfect puddling, also where there was a rich iron giving off a thick slag which did not get away and was rolled into the plate, imprisoned gases, &c.

In reply to Mr. Lowe malleable iron could not be mixed with wrought iron scrap and welded up, as, if possible, it was even worse than steel.

A very cordial vote of thanks on the motion of the President, seconded by Mr. West, was passed to Mr. Webb for his paper, which he acknowledged, and the proceedings concluded.

DIAGRAMS.

IRON MANUFACTURE.



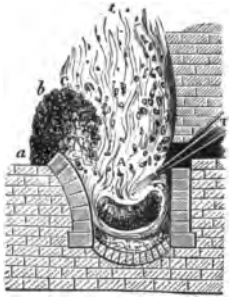
HINDOO FURNACE.

ESTER ASSOCIATION OF ENGINEERS.

UNIV. OF MICH.

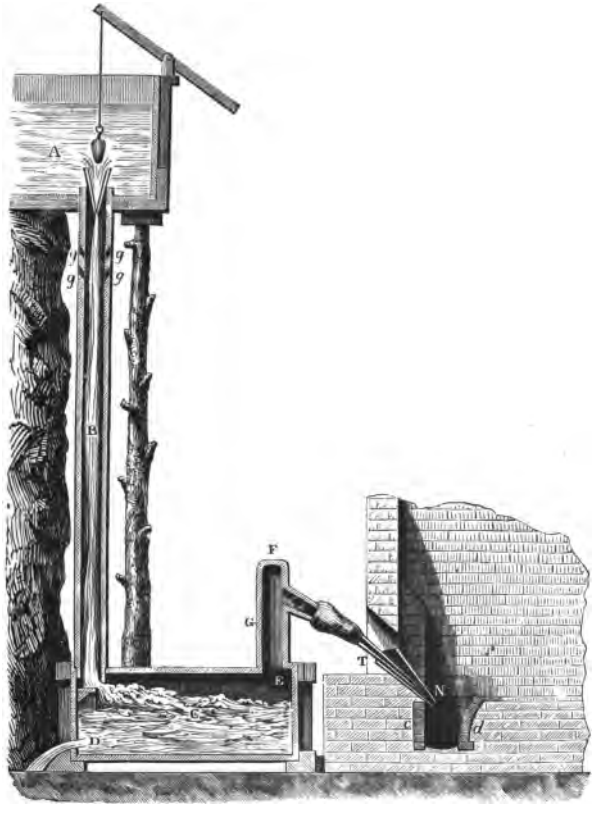
IRON MANUFACTURE.

Fig. 1.



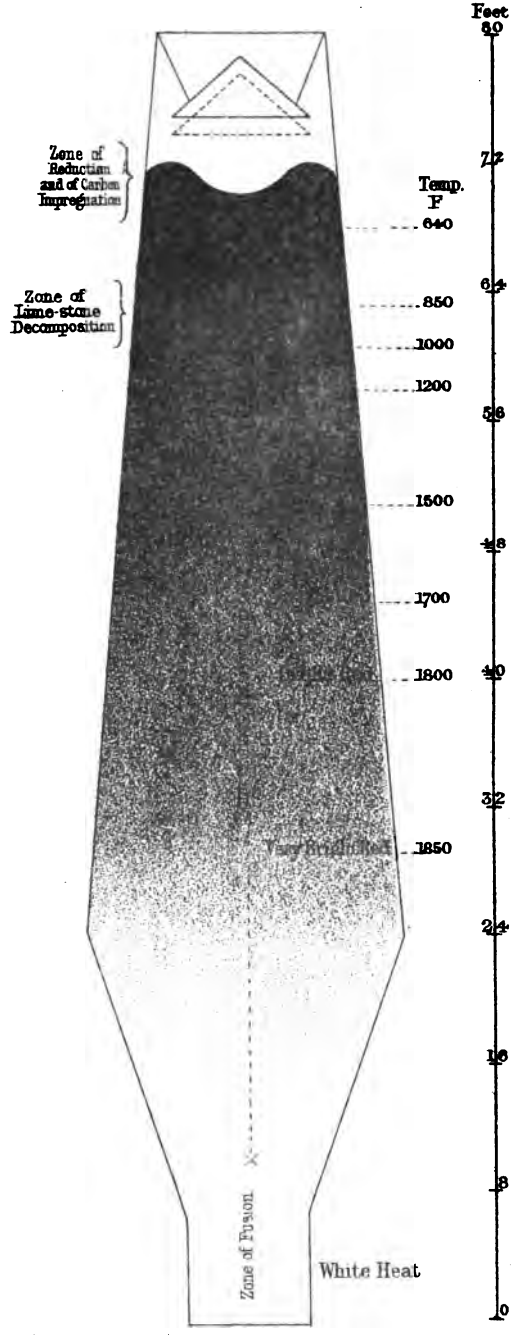
CATALAN FORGE.

Fig. 2.



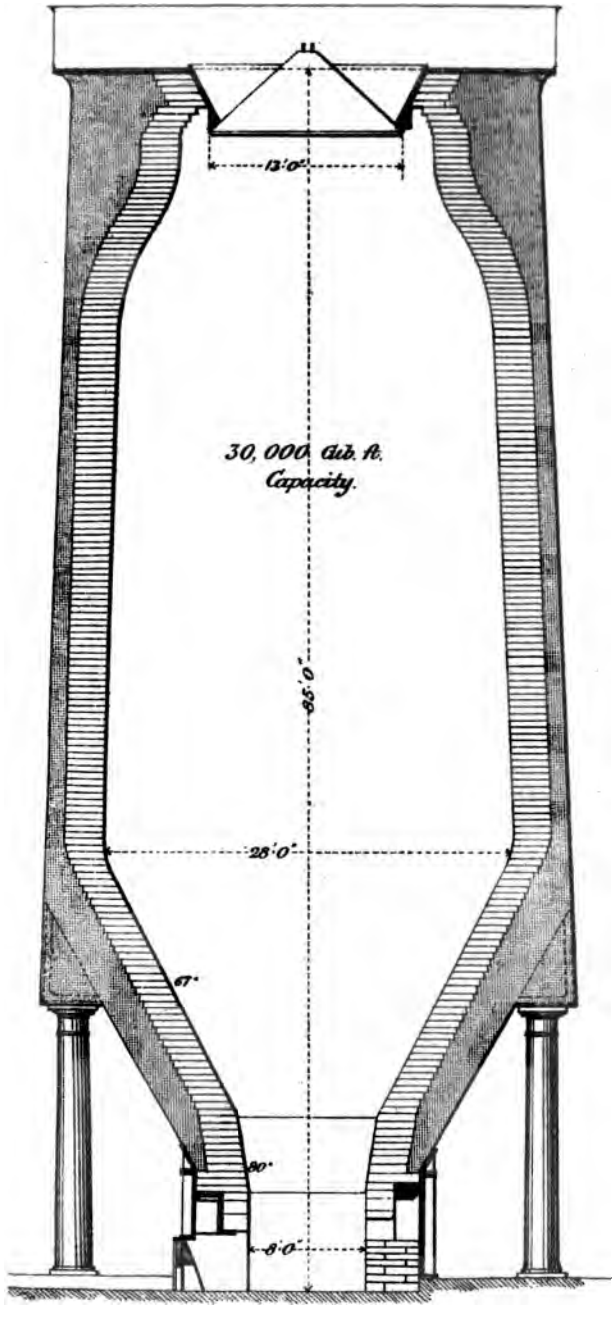
CATALAN FORGE.—TROMPE.

IRON MANUFACTURE.



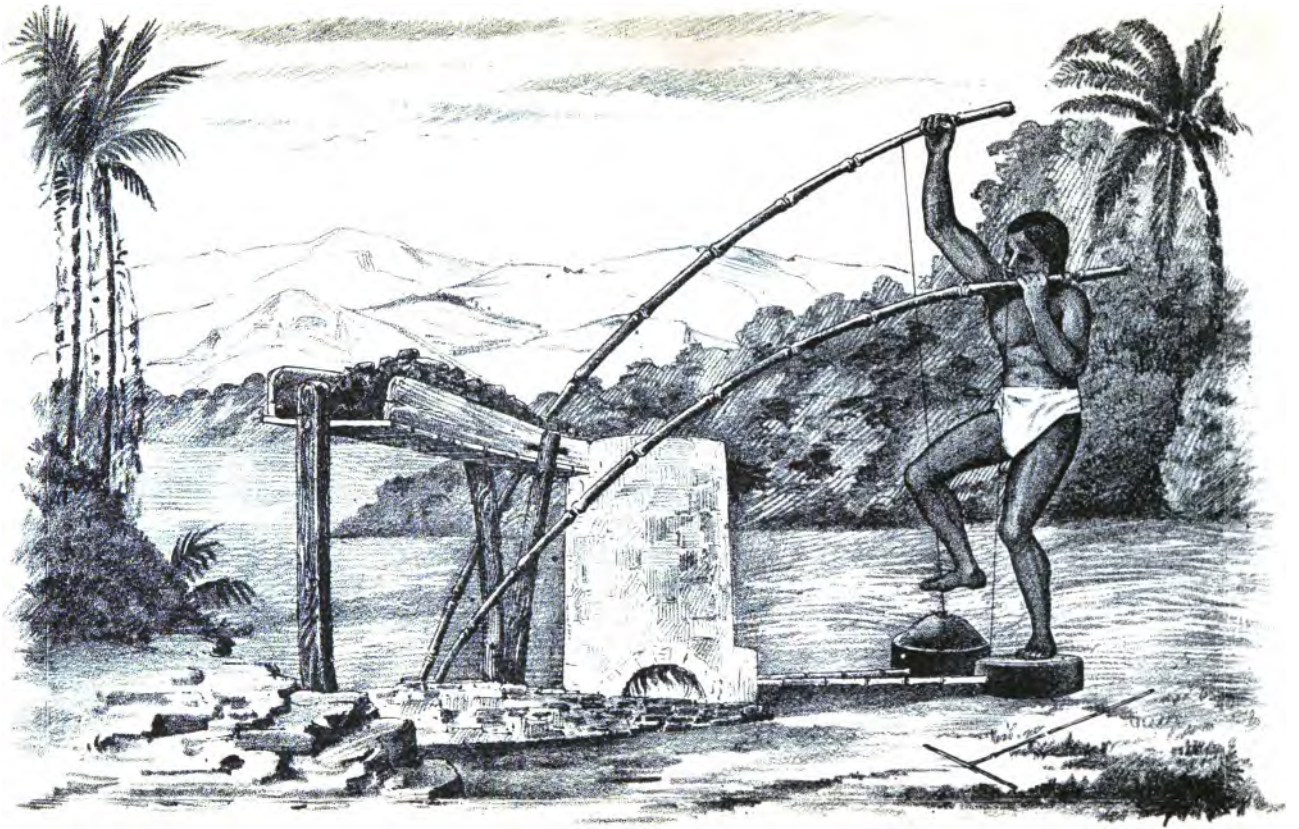
TEMPERATURE OF BLAST FURNACE.

IRON MANUFACTURE.



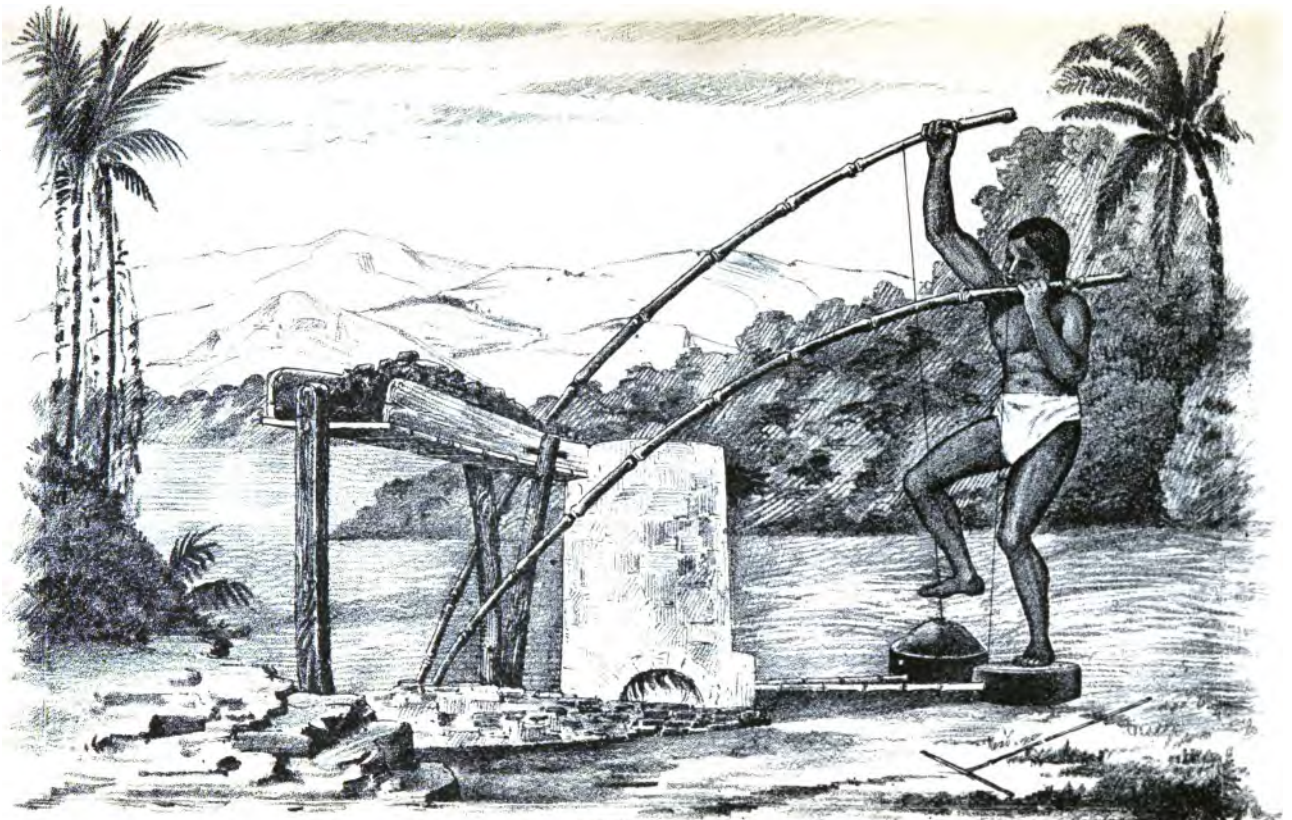
CLEVELAND BLAST FURNACE

IRON MANUFACTURE.



HINDOO FURNACE.

IRON MANUFACTURE.

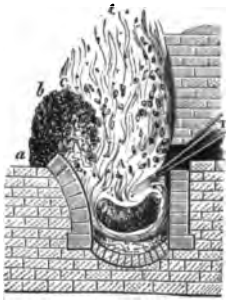


HINDOO FURNACE.

UNIV. OF MICH.

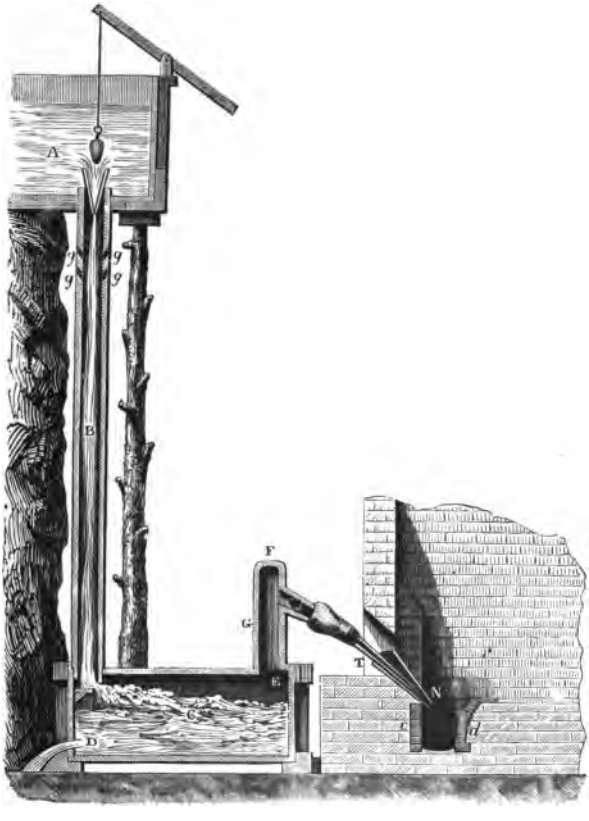
IRON MANUFACTURE.

Fig. 1.

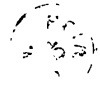


CATALAN FORGE.

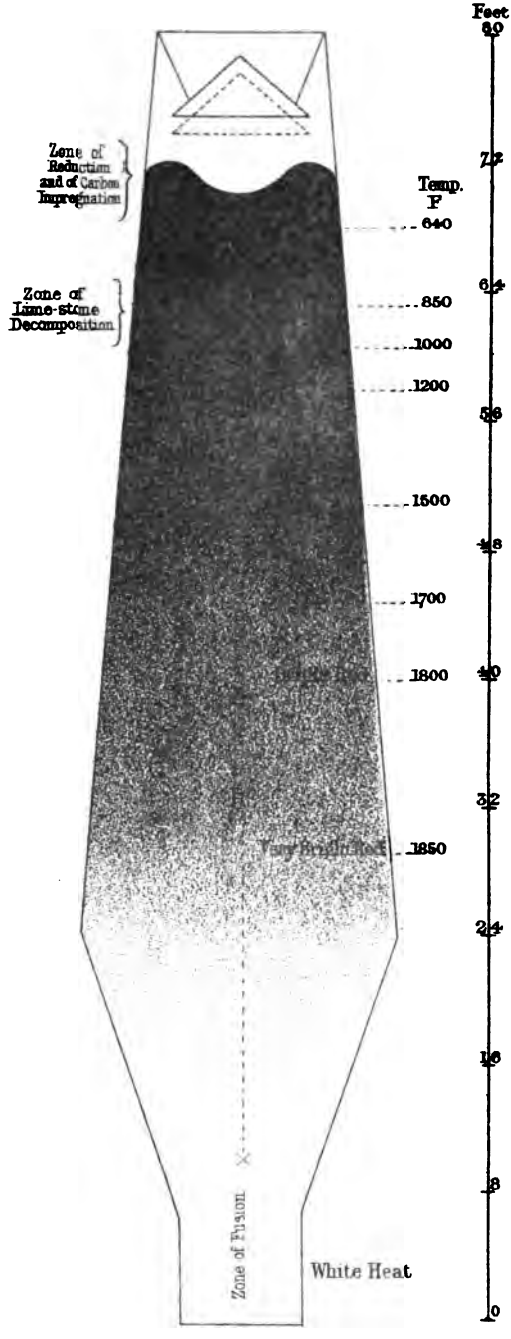
Fig. 2.



CATALAN FORGE.—TROMPE.

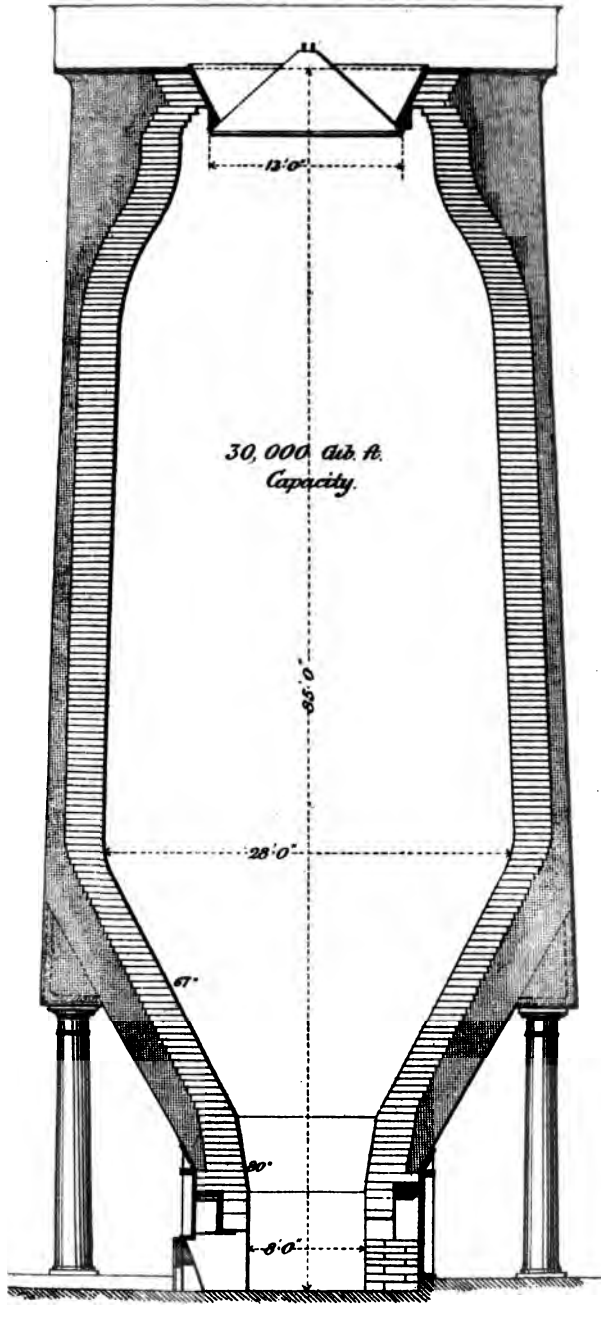


IRON MANUFACTURE.



TEMPERATURE OF BLAST FURNACE.

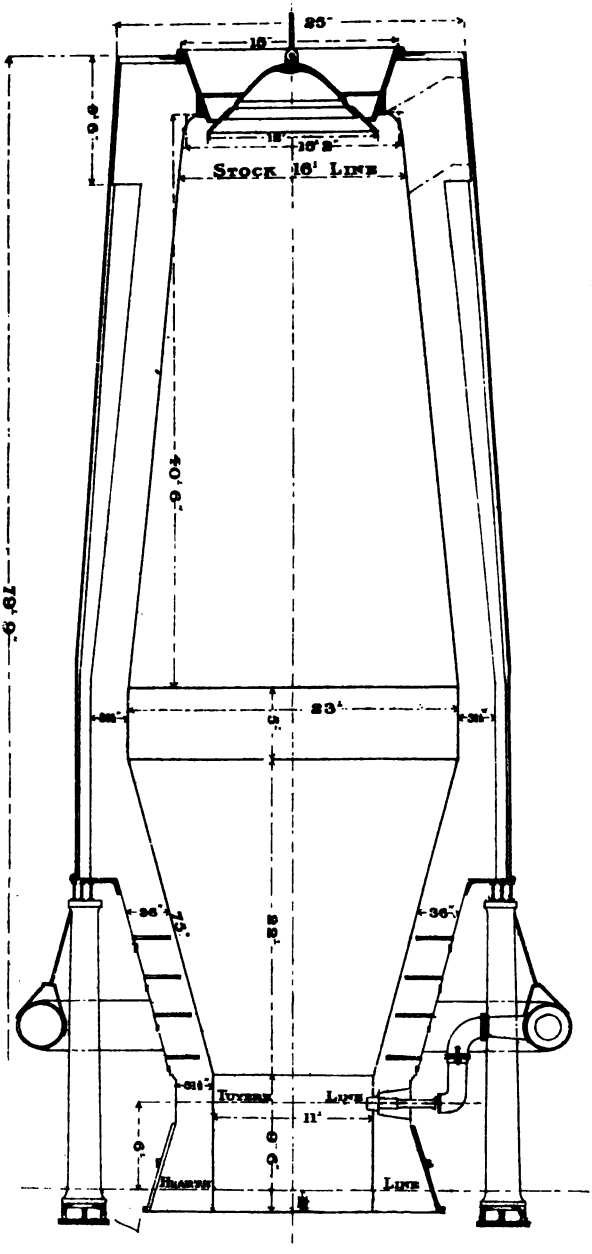
IRON MANUFACTURE.



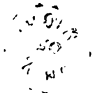
CLEVELAND BLAST FURNACE.

UNIV OF NORWICH

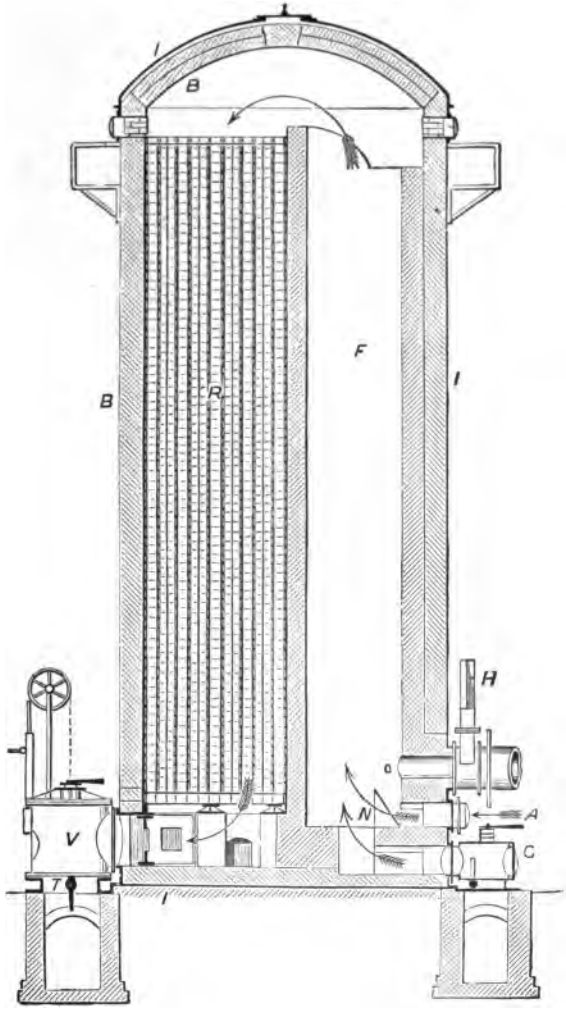
IRON MANUFACTURE.



AMERICAN BLAST FURNACE.



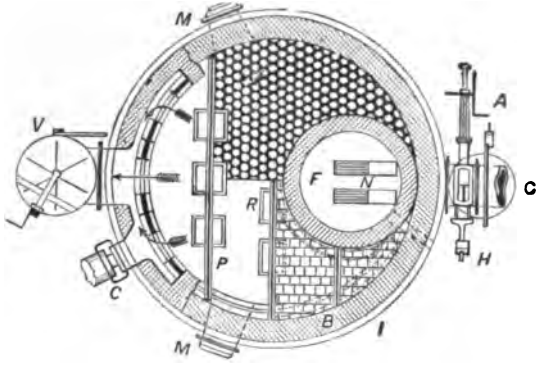
IRON MANUFACTURE.



COWPER'S STOVE.—VERTICAL SECTION.

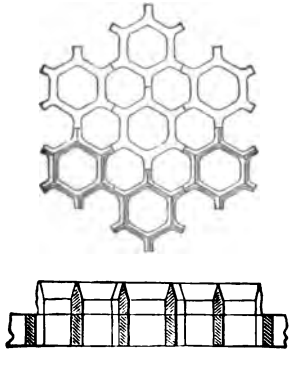
IRON MANUFACTURE.

Fig. 1.



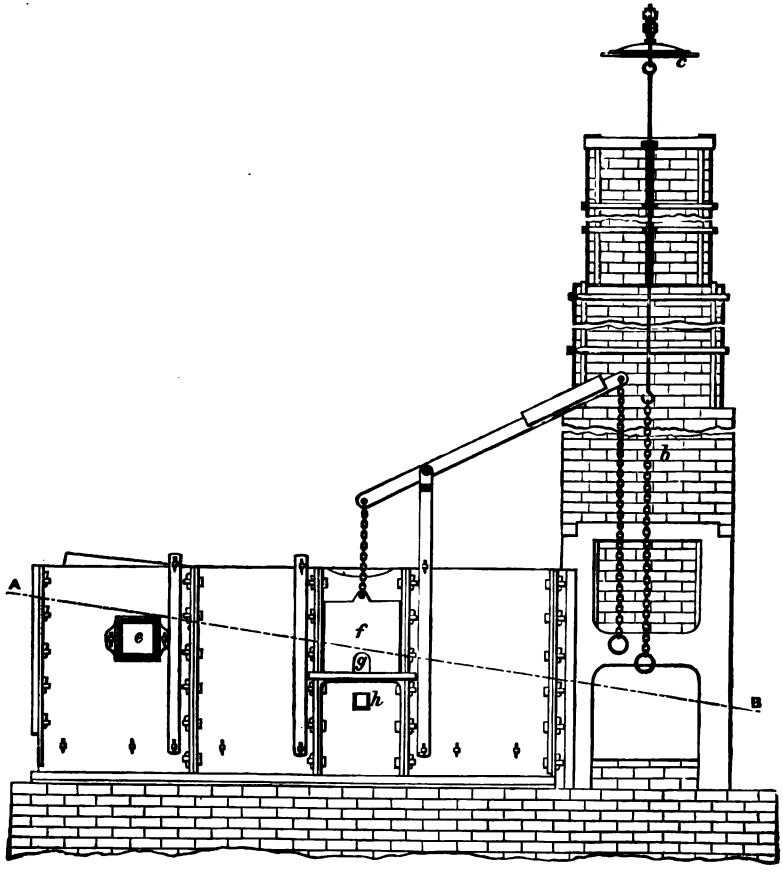
COWPER'S STOVE.—HORIZONTAL SECTION.

Fig. 2.



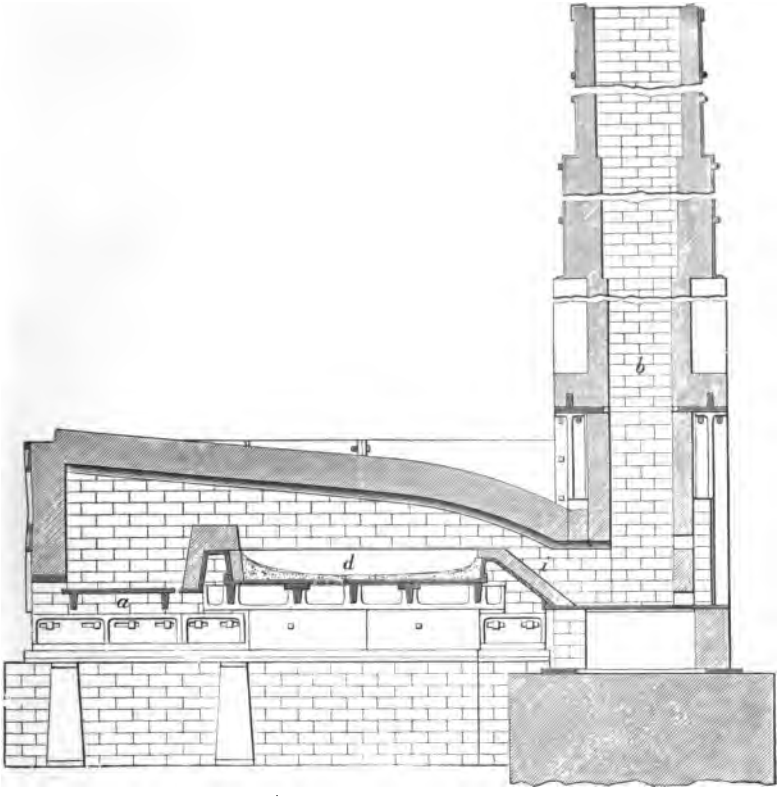
COWPER'S STOVE.—DETAILS OF BRICKWORK.

IRON MANUFACTURE.

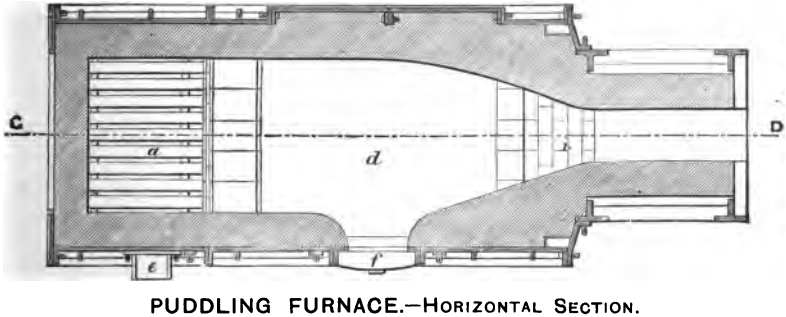


PUDDLING FURNACE.—SIDE ELEVATION.

IRON MANUFACTURE.

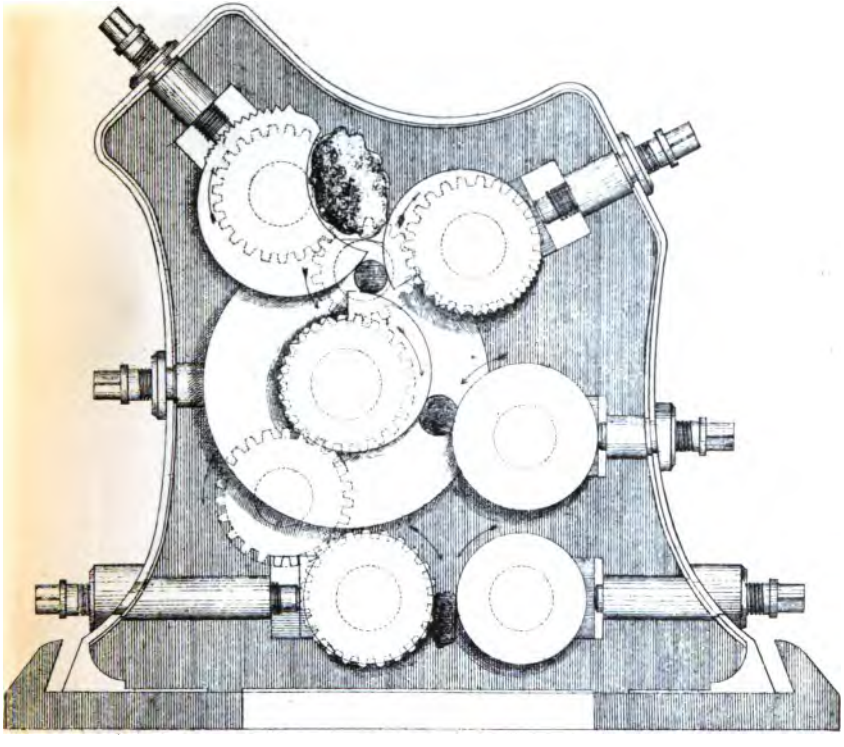


PUDDLING FURNACE.—VERTICAL SECTION.



PUDDLING FURNACE.—HORIZONTAL SECTION.

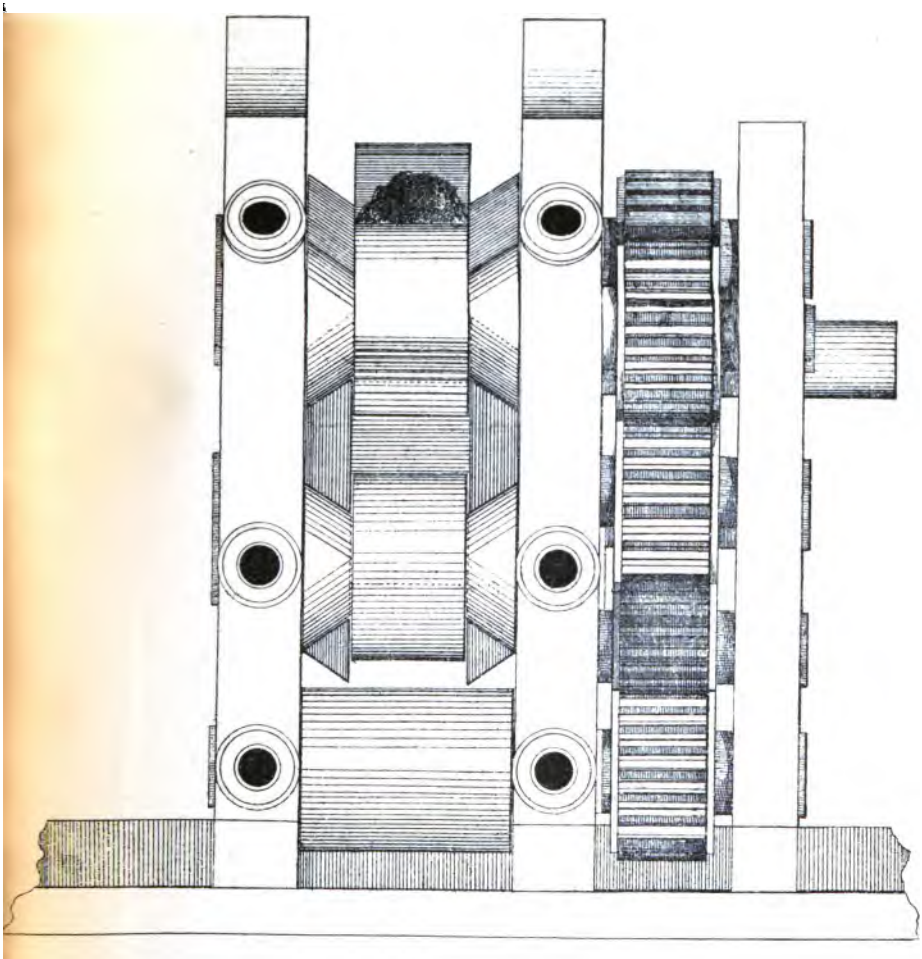
IRON MANUFACTURE.



SQUEEZERS.

SIDE ELEVATION WITH END PLATE REMOVED.

IRON MANUFACTURE



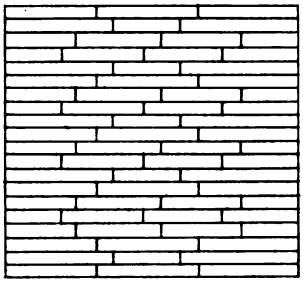
SQUEEZERS

FRONT ELEVATION

UNIV. OF MICH.

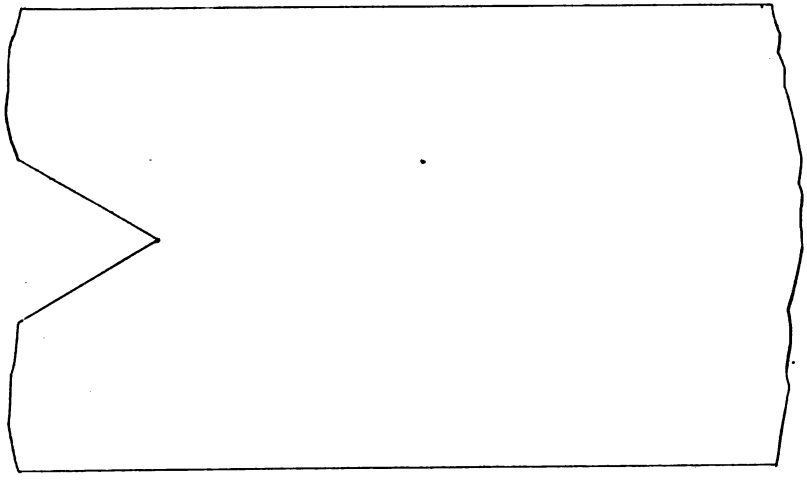
IRON MANUFACTURE.

Fig. 1.

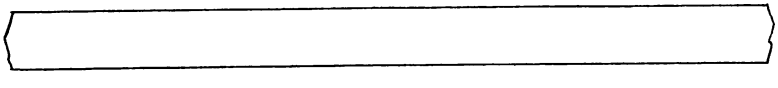


PILE.

Fig. 2.



SLAB.

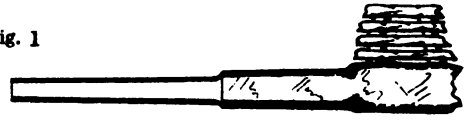


SLAB.

IRON MANUFACTURE.

METHOD OF FORGING MARINE CRANK SHAFT.

Fig. 1

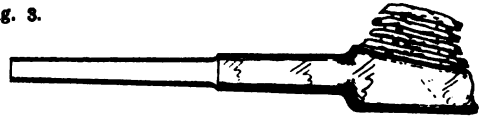


Porter Bar with slabs for laying up.

Fig. 2.

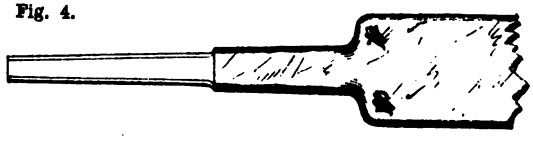
Laid up and then set down to dotted lines

Fig. 3.



More slabs—laying up

Fig. 4.

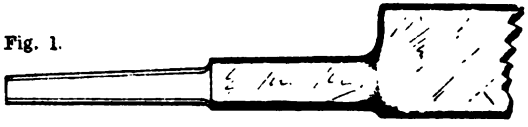


Flattened

IRON MANUFACTURE.

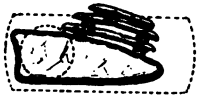
METHOD OF FORGING MARINE CRANK SHAFT.

Fig. 1.



Set to one side of porter.

Fig. 2.

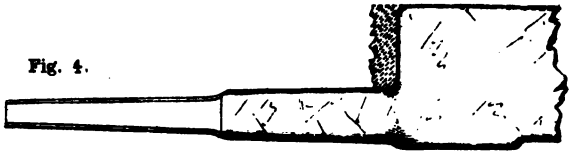


Tapering one side—more slabs.

Fig. 3.

Method of placing slabs for web of crank

Fig. 4.

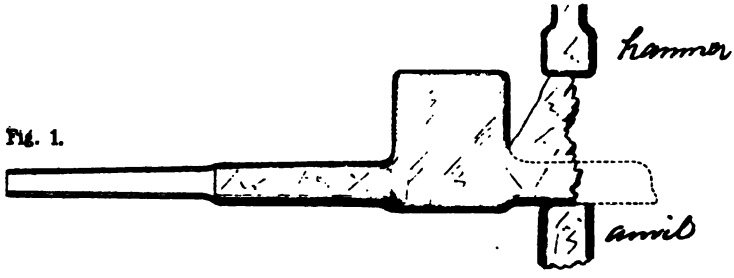


Side of web nearest porter cut out.

IRON MANUFACTURE.

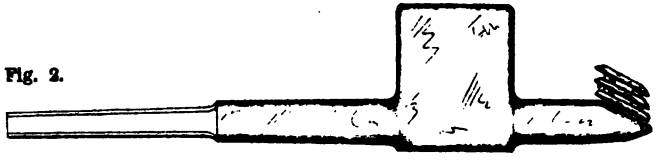
METHOD OF FORGING MARINE CRANK SHAFT.

Fig. 1.



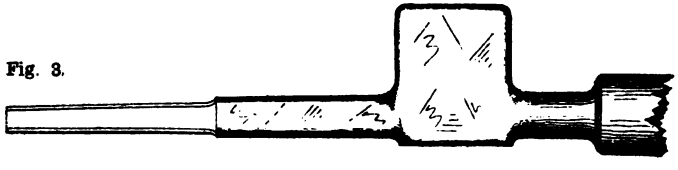
Other end of web cut, hammered down as dotted

Fig. 2.



Laying on more slabs.

Fig. 3.



Boss formed for collar.

Fig. 4.

Method of welding on the collar.

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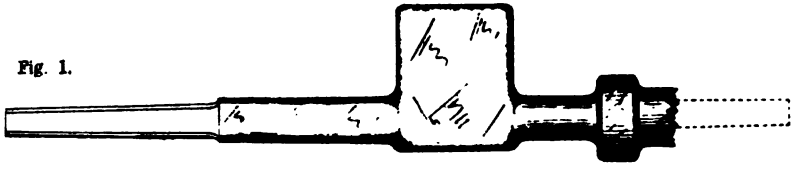
IRON MANUFACTURE.

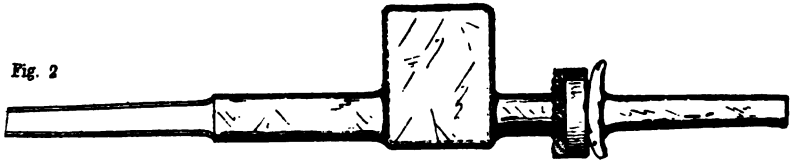
METHOD OF FORGING MARINE CRANK SHAFT.

Fig. 1.



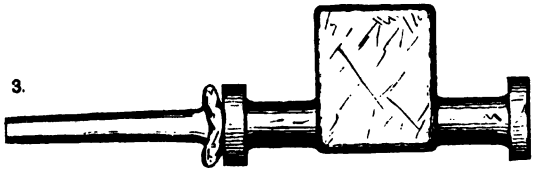
Making new porter bar from collar

Fig. 2



Finishing collar.

Fig. 3.

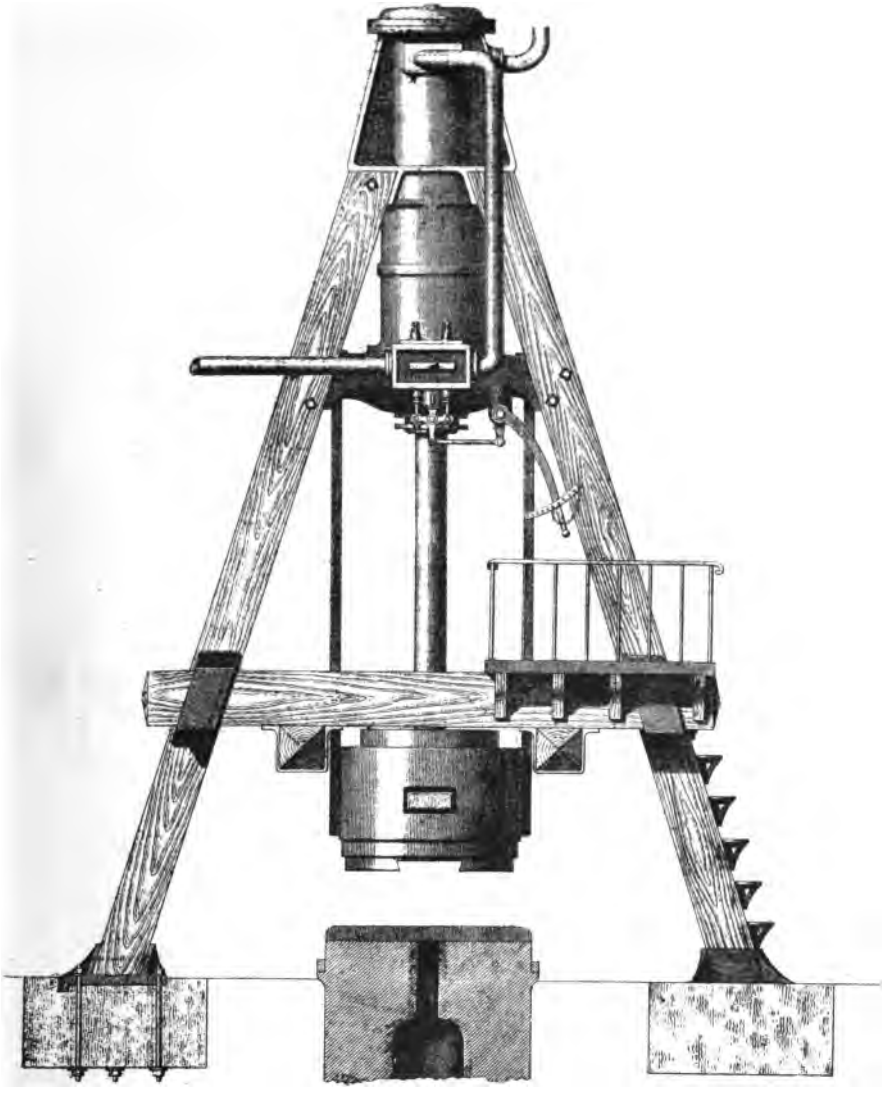


Finished crank forging.

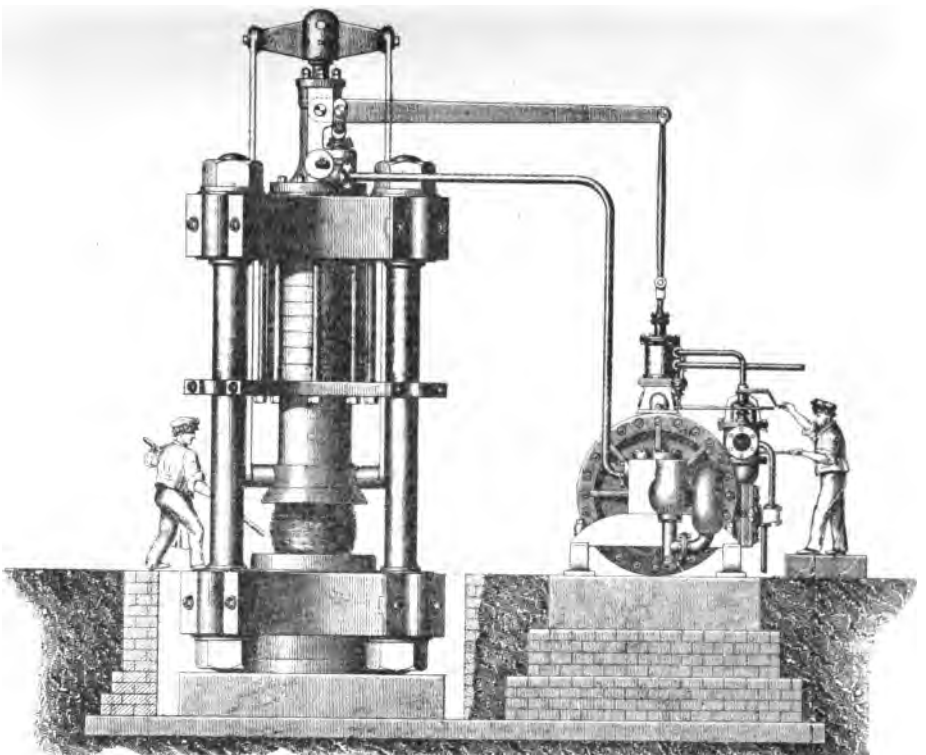
IRON MANUFACTURE.

DROP HAMMER.

IRON MANUFACTURE.

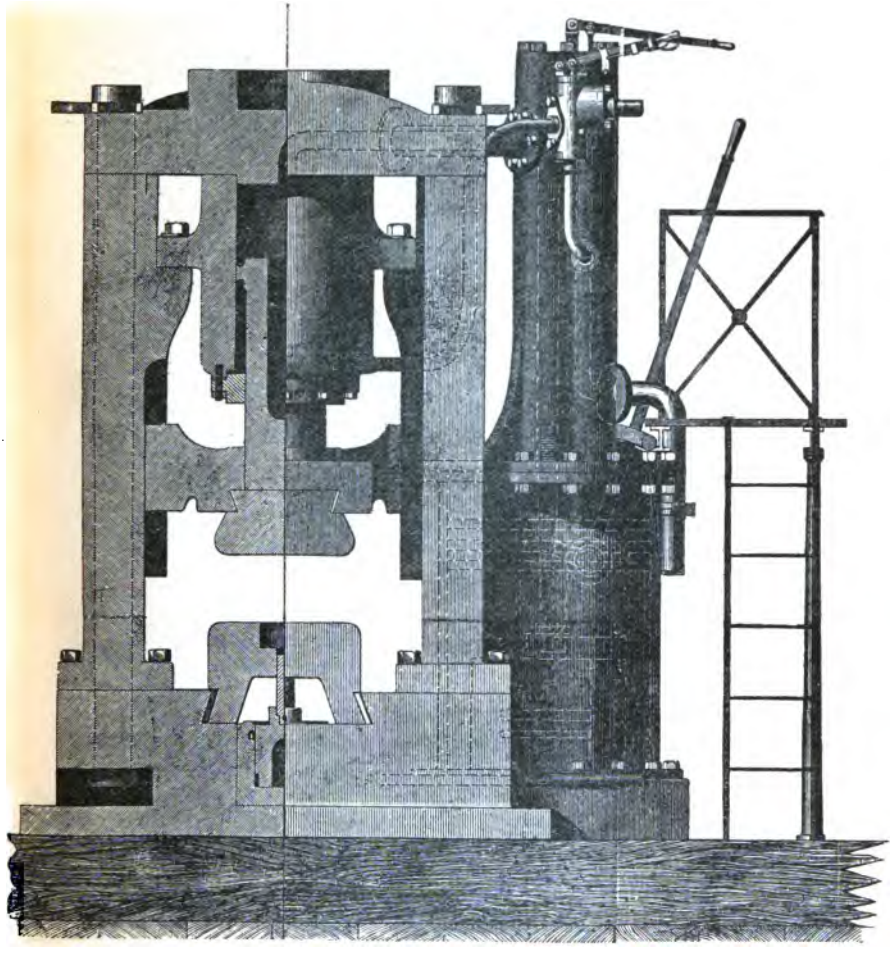


ARBEL'S DROP STAMP



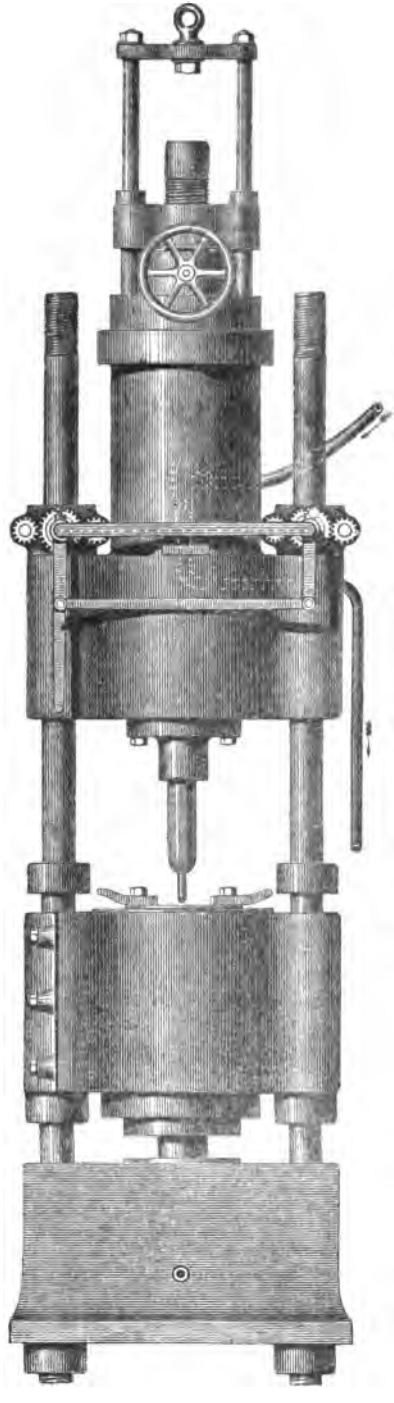
HASWELL'S FORGING PRESS.

IRON MANUFACTURE.



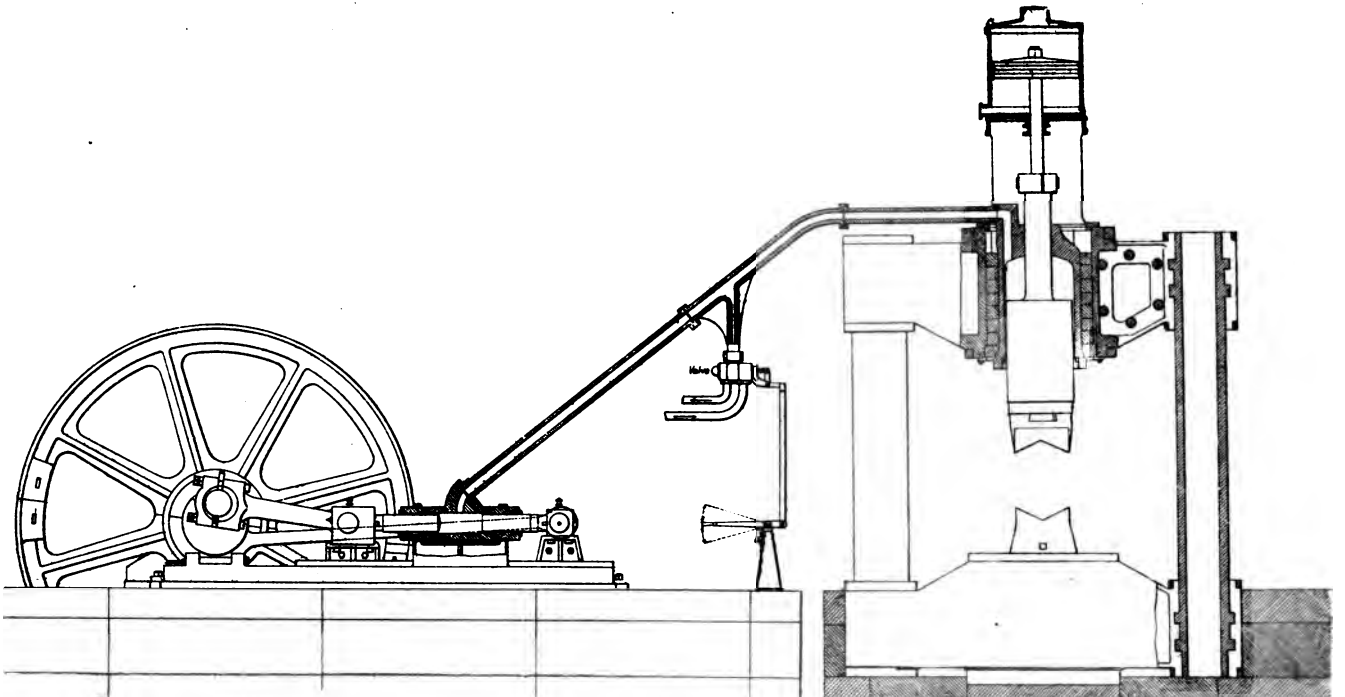
SHANKS & KOHN'S PATENT HYDRAULIC FORGING PRESS.

IRON MANUFACTURE.



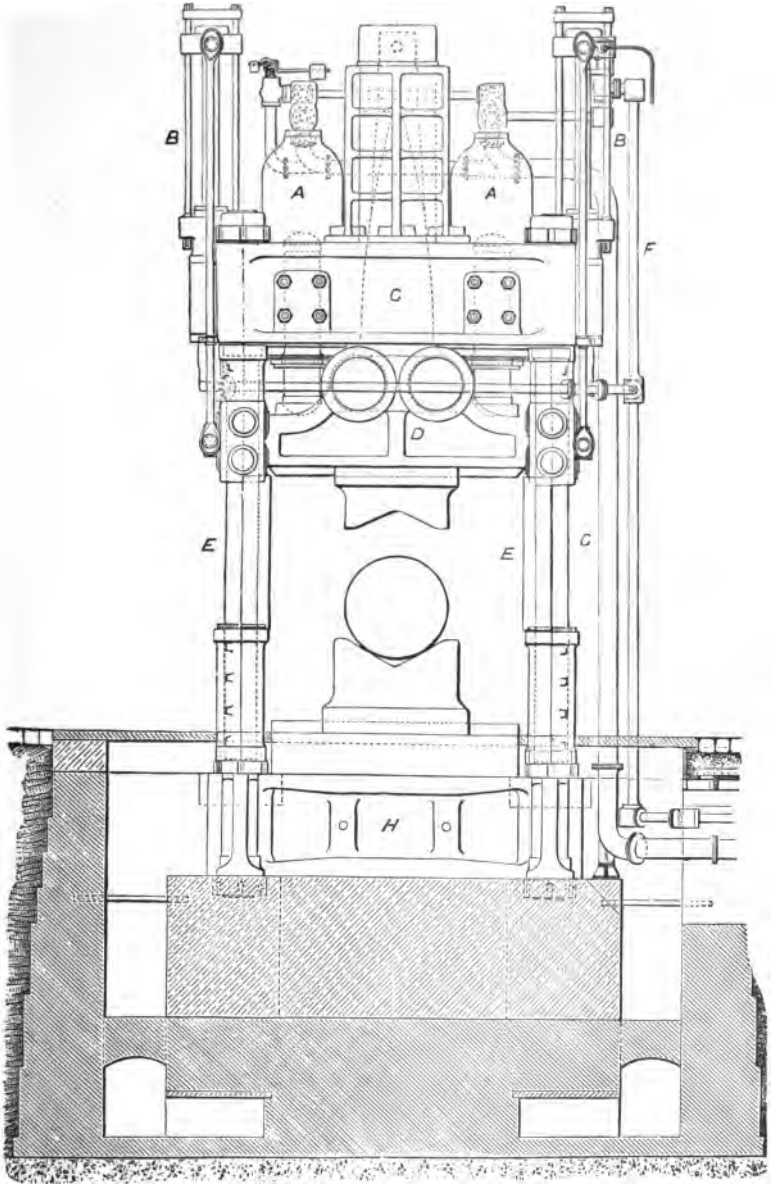
SIR J. WHITWORTH'S PRESS.

UNIV. OF MICH.



HYDRAULIC FORGING PRESS.

IRON MANUFACTURE.



HYDRAULIC FORGING PRESS

UNDOC

DRY-AIR REFRIGERATING MACHINERY;

ITS COMMERCIAL VALUE,

BY

MR. W. G. QUICKE,

(OF MANCHESTER.)

READ SATURDAY, 26TH MARCH, 1892.

The growing importance and rapid development of the various systems of Dry Air Refrigeration during the past 18 years has revolutionised the food supply of this country; and the ever increasing demand, not only for frozen meats, but for dairy produce and fruit, imports which necessitate the use of cooling machinery, all tends to encourage this branch of engineering industry; while vast tracts of hitherto uncultivated country in New Zealand, Australia, and River Plate, S.A., particularly, are now flourishing pasture lands and the centres of combined abbatoirs and freezing stores fitted with every requisite that modern invention can suggest for the preparation and export of frozen meats.

Before entering upon the subject of modern machinery a short sketch of the early inventions and experiments may be an advantage.

The principal object of earlier inventors appears to have been to produce ice artificially for commercial purposes, and although several had succeeded in producing ice in small quantities, nothing material was effected until early in the present century when Mr. Nairne discovered that by passing sulphurous acid into an exhausted receiver it had the property of absorbing aqueous vapour from air, and in 1824 John Vallance acting upon this property constructed a machine by which he circulated dry rarified air over water to be frozen.

The heat and vapour of the water was absorbed by the air which passing into the receiver was in turn redried by the sulphurous acid.

Edmond Carré improved this process by keeping the acid agitated by means of a lever attached to the air-pump.

In 1834 the principle of compression was introduced by Perkins, who compressed ether, cooled it by water, and vaporised it in a refrigerator.

Faraday's discovery in 1823 of the qualities of ammonia created considerable interest, as this gas possesses a much wider range of temperature for the production of ice, its boiling point being −37·8 F, and Ferdinand Carré availing himself of this property constructed an intermittent apparatus on the absorption principle, composed of a boiler in which the liquid ammonia mixed with water was evaporated, and a refrigerator immersed in a tank of cool water. The temperature of the ammoniacal liquor in the boiler was raised to 284°F corresponding to a pressure of about 150lbs. per square inch. As the ammonia is given off it passes into the refrigerator, where, assisted by the cooling influence of the water, it is condensed by its own pressure to the liquid form. The boiler with its contents is then allowed to cool which removes the pressure from the liquid ammonia causing it to re-evaporate and in so doing it absorbs heat from the water in the tank, converting it into ice.

Doctor John Gorrie, of New Orleans, prosecuted some experiments on the compression and expansion of atmospheric air, and in 1845 he constructed a machine for the purpose, which consisted of a double-acting compressor pump, a worm or cooler, and an expansion cylinder and piston.

During compression he injected cold water into the cylinder which reduced the temperature, the water passing with the compressed air into the cooler where it was drained off; while the cooled air entered the expander, acting upon the piston and returned a percentage of the power given out during compression. During expansion brine was injected, which loosing its heat to the expanding air was discharged and circulated around the vessels containing water to be frozen.

In 1848 Professor Twinning, of New Haven, in the course of some experiments with ether discovered that by the evaporation of 1lb. of ether he obtained a little over 1lb. of ice from

water at 32° F in addition to recooling the ether under compression.

In 1850 he constructed a machine which consisted of a double-acting pump, a condenser, and a refrigerator. The ether was compressed into a condenser formed by a series of coils surrounded by cooling water, which liquified the gas, it being drawn by a vacuum pump into the refrigerator where it vaporised, reducing the brine to below 32° F. This method of freezing the water in iron moulds around which the cold brine circulates is precisely the system adopted to-day in ice factories on a large scale.

In 1855 Harrison, of Australia, invented a process, the medium being ether and similar to Twinning's in principle but varying in detail; and in 1857, Doctor Siemens made an improvement on Dr. Gorrie's machine, by which he purposed cooling the compressed air by the waste cold air from the expander.

In 1859 Ferdinand Carré produced his continuous acting ammonia freezing machine on the principle of absorption, being an improvement on his intermittent apparatus. He added a feed connection to the top of the boiler and through this a continual supply of strong solution replenished the impoverished liquid at the bottom, and as the heat drove off the aqueous vapours containing from 85 to 90 per cent. of ammonia, it passed through a condenser consisting of a series of coils surrounded by cooling water, where by pressure resulting from distillation and the cooling effects of the water it was liquified. The pressure on the boiler and condenser equalled 10 atmospheres or nearly 150lbs., but on leaving the condenser the liquified solution passes into a regulator where the pressure does not exceed 1½ atmospheres; from this it passes into the distributor and expands into the refrigerator, absorbing heat from the vessels containing water to be frozen, and returning vaporised into the absorber. It thus comes in contact with the condensed cooled water from the boiler, and being reabsorbed forms a fresh strong solution which is passed into the boiler by a special pump for the purpose, thus completing the cycle of operations. Although a cheap and simple contrivance, the machine was too expensive to work, requiring a very large

quantity of cooling water, besides fuel for the evaporator and force pump separately.

Reece improved this arrangement by causing the ammonia vapour from the refrigerator to pass through an ordinary cylinder fitted with slide valves, similar to a steam engine, and in this way utilizing the waste, or returning gas, to work the pump, which reduced the cost of fuel to that of the evaporator alone.

In 1861-2 Dr. Kirk constructed a machine for making ice on the principle of compressed air, following Doctor Gorrie's idea of expansion, but using a regenerator (on the principle of Stirling's air engine) between the compression and expansion cylinders.

During compression the air is cooled by a circulation of cold water, and on the other side of the regenerator the expanding air cools an injection of brine. The compression in this machine was practically isothermal, and it was necessary to inject brine during expansion, otherwise the regenerator would have been choked with snow, and in a small model Dr. Kirk succeeded in freezing mercury. (See paper by Dr. Kirk, read before Institute of Civil Engineers, March 20th, 1884.)

In 1869 Windhausen, the German engineer, patented a machine on the system of compressed air; he constructed a cylinder by which he compressed on one side of the piston and expanded on the other, suitable metallic valves being fitted into the covers at each end of the cylinder, and when two cylinders were employed the machine became double acting. From the compressor the air was made to pass through a cooler having two compartments, in one of which it was cooled by a constant flow of cold water (which also circulated around the compressor by means of a jacket), and in the other by the cooled air from the refrigerator on its passage back to the compressor, similar in part, with the exception of a temperature regulator used by Windhausen, to the cold air machine produced by Messrs. Bell Coleman at a later date on a larger and more substantial basis. Windhausen's refrigerator was a rectangular chamber constructed of wood, the spaces between the casing being fitted with non-conducting material; the cover having openings, fitted with metallic cases containing vessels of water to be frozen.

Zig-zag partitions were fitted between the cases inside to ensure an equal distribution of the cold air, and an india-rubber bag was employed to regulate the pressure in the refrigerator, which emitted, or admitted air as required.

In 1873 Paul Giffard patented a machine in which he cooled the air under compression by direct injection, otherwise the apparatus resembled Windhausen's in principle, but in both machines the difficulty which prevented their commercial success was the formation of ice and snow in the expanders to such an extent as to choke up the air passages.

But Windhausen was undaunted by his failures, for a few years later we find him reverting to the chemical machine by absorption in which he employed sulphurous acid in connection with a vapour and vacuum pump; the process being to place the water to be frozen under a vacuum, the vapour from which passing through an absorber, containing sulphurous acid in agitation, was absorbed until the heat and vapour all being drawn off, ice of a porous nature, consequent upon the vacuum, was found in the vessels.

The acid on becoming surcharged with vapour overflowed into a concentrator, formed by hot steam pipes, where, the water being evaporated and drawn off by a special vapour pump, the acid was returned to the absorber.

A plant on this principle was put down at the Aylesbury Dairy Company's premises at Bayswater, London, in 1882, and was described in the "Engineer" of October 20, 1882, and was said to produce 12·5 tons of ice per ton of coal consumed. A machine also on this principle, but substituting a hot jacketed vapour pump in place of the acid, is now made by Messrs. Southby & Blythe of Layton, Essex.

In 1876 Mr. Coleman of the Bell-Coleman Mechanical Refrigerating Company, Glasgow, brought out a patent on the compressed air system for the purpose of importing dead meat. Hitherto inventors had not given their attention to this branch of refrigeration, and the subsequent success of Mr. Coleman's machine demonstrated the wisdom of the promoters. The second machine fitted up by this Company was put on board the Anchor Line s.s. "Circassia" in March 1879.

This machine was duplicated in all its parts, so that in the event of a breakdown one side could be worked while the other was under repair; and Mr. Coleman in his paper read before the Institute of Civil Engineers in February, 1882, gives particulars of this machine, which was constructed with 4 vertical steam cylinders each 10in. diameter and 16in. stroke, placed above the crank shaft to economise room, and working with return connecting rods; the two compressors 16in. diameter, and 2 expanders 12in. diameter, all 16in. stroke, were placed horizontally, the compressors behind the expanders in pairs to facilitate duplication. Mr. Coleman had adopted the injection principle, part of the water being injected into the compressor during compression, and part being admitted into a tower through a rose at the top, the air ascending through the perforated plates of the tower, meeting the spray of water, passed out through the side of the tower near the top into the drying pipes where the compressed air was subjected to a current of cold air returning from the rooms, as shown in part on Plate 1, Fig. 1; C being the compressor, the air instead of passing into the water cooler DD as shown, was passed into the tower fixed on the side of the machine, the top part of which was connected to the pipe E so that the tower was simply a substitute for the coolers and *vice versâ*. An automatic ball trap was connected to the bottom of the tower to drain off the water accumulated from the compressor and tower, and the air passing up through the perforated plates deposited any moisture; then entering the pipe E it passed into the drying pipes D P by the chamber I, and traversing the lower pipes into No. 2 returned by the top pipes into chamber 3, entering the pipe F it passed into the expander E X where giving out its heat behind a piston during expansion it was discharged, and entering the trunk G passed into the cold room H where the cargo of meat is stored; after circulating through the room, or hold, the warmer air rising to the surface returned by suction through the apertures in the trunk A, and circulating around the pipes in D P, cooling and drying the air under compression, it returned by the pipe B into the compressor to repeat the process. Drain pipes were fitted to the bottom of chambers 1 and 2 in D P to draw off any water collected from the air in the process of drying.

The water tower arrangement is shown on Plate 8, Fig, 1 in plan, and in this instance it is fitted between the water cooler and drying pipes as an addition, injection not being used in the compressors.

Meanwhile the steamship "Strathleven," owned by a London firm, was fitted with a single machine for an experimental voyage to Australia; the room was about 4,000 cubic feet capacity, and insulated with 10in. thickness of charcoal. This vessel returned to London on the 1st February, 1880, with a cargo of mutton and beef weighing about 84 tons, in first-class condition, and being the first successful cargo from Australia, it established the reputation of the Bell-Coleman machine.

In April, 1880, Messrs, J. & E. Hall, of Dartford, produced a compressed air machine on the surface cooling principle; the air, after being compressed, passed through vessels surrounded by water, and being cooled in this manner it was directed into vessels containing perforated plates, where the vapour, held in mechanical suspension, was precipitated as water, the dry air passing into the expansion cylinder and finally discharged.

This firm fitted machines on ships belonging to the Peninsular and Oriental Steam Navigation Company for the Eastern trade, and two machines were sent out to Australia for cold stores, and Messrs. Robinson Bros., of Melbourne, endeavoured to copy one of these, which they fitted on board the S.S. "Protos," which brought the second cargo of meat from Melbourne.

A great impetus was now given to the manufacture of refrigerating machinery, and in the same year Mr. (now Sir) A. S. Haslam, of Derby, brought out a machine on the surface-cooling principle, otherwise much on the same lines as the Bell-Coleman machine, with the exception of the expanding cylinder, which he constructed, having two separate valve faces; the top set of valves, or those admitting dry compressed air into the expander, being ordinary Meyer slides and expansion cut-off valves without exhaust port in the main slide; the exhaust or discharge valves being placed on the side of the cylinder, as shown by figures 5 and 6 on Plate I., the valves A being connected on the rod by a distance piece or sleeve B, and kept in position against the cylinder face by the square bars of steel C, which are held by setting-up screws. These valves required very careful setting,

but their advantage lay in the very short passage from the cylinder, the large area for the discharged air into E X, and from the fact of a wood cover only being required, the valves could be got at and the snow cleared away without stopping the machines.

Early in 1881 the Haslam Foundry and Engineering Company fitted one of these machines, having a delivery of 40,000 cubic feet of air per hour, on board the S.S. "Orient" and on October 4th following, this vessel brought her first cargo from Australia into London, consisting of 8,170 carcases of mutton and 70 quarters of beef, in all about 150 tons. This was the first experiment with the Haslam machine on board ship, and its success was as marked as the construction and finish of the machine was substantial.

Messrs. Hick, Hargreaves & Co., of Bolton, also at this time constructed Cold-Air machines of the Giffard type, using the water injection with the drying process, and fitted one on the S.S. "Sorrento," but the results were not so satisfactory as anticipated.

Such was the position of the Cold-Air machine in 1881, and no material departure from the principles of its application at that date have since been made; improvements have necessarily followed, but these bear more directly upon the details of construction.

During this time promoters of the ammonia process had not been idle, for we find that about the year 1878 Prof. Linde, of Wiesbaden, had taken out a patent on the ammonia compression system, and subsequently the Linde British Refrigerating Company was formed, with headquarters in London, to produce these machines, yet not one was put on shipboard by this Company until their 424th machine was made in 1886, when they fitted a vessel, belonging to Marseilles, for the carriage of fish.

Meanwhile in 1878, Mr. John De La Vergne, of New York, constructed an experimental machine on the ammonia compression system for cooling purposes in a large brewery, but this was a failure; profiting by his experience, he constructed another machine in 1880, upon the results of which the De La Vergne Refrigerating Machine Company was formed.

The good results obtained by these machines are mainly due to the method of oil sealing adopted in the compressors.

To effect this the cylinder is vertical, and longer than usual, having a space between the under side of the piston and bottom cover, which by an arrangement of valves and a pump is kept filled with oil, thus effectually sealing the stuffing box and leaving no clearance spaces. By the up stroke the ammonia vapour is drawn into the cylinder, and passes through the valve in the piston during the down stroke; the lubricant is injected during the down stroke, and the piston becoming submerged in this at the bottom, a quantity passes through the valve and effectually seals the upper surface, so that every trace of ammonia is expelled with the oil, the latter absorbing a large amount of the heat generated.

The lubricant passes with the ammonia into the separator, where the former gravitating, the hot gas rises into the condensers, and the hot oil passing into a special cooler, from thence through a strainer to the oil tank, is again injected into the cylinder by a small pump worked from the engine.

The ammonia gas compressed to an average of 150lbs., varying in proportion to the cooling efficiency of the water, passes into the condenser at the bottom; the tubes, 2in. in diameter, of patent screw, and soldered joints, are placed horizontally, and in stacks, uncovered and convenient to get at separately. The cooling water is directed to fall on to the top tube of each stack, and by fitting a piece of sheet metal between each tube the water trickles down over the entire surface meeting the warm gas as it rises in the tubes until liquefaction takes place. A series of small tubes called "liquid pipes" are connected at various heights in each condenser stack to carry away the liquefied gas, and then connecting to one large pipe the liquid is collected from the separate sections of the coils and so maintains the condenser as dry as possible. The advantage claimed by this system is that a smaller quantity of water is used, and each stack or coil of pipes can be separated from the rest at any time to be cleaned and painted as desired, without interfering with the working of the machine. From the liquid pipes the ammonia now passes into the expansion coils, its passage being regulated by the expansion cock so as to maintain a pressure

therein of from 20 to 25lbs. These coils are similar in structure to the condenser, and when used for cold stores are generally fitted in the room to be cooled either overhead or along the sides, and in this system a series of cast-iron discs are fitted at intervals on the pipes by means of clips, thereby exposing a larger cooling surface to the air in the room.

The ammonia traverses these pipes absorbing heat from the air of the room inducing vaporization and returning to the compressor at the pressure existing in the expansion coils.

Several plants on this system have been erected in Britain, by Messrs. L. Sterne & Co., London and Glasgow, who have the right of production for Great Britain and the Colonies.

Reverting to the cold dry air machine, which in the course of about two years had undergone many improvements, Messrs. Bell-Coleman having discarded the old type as fitted on the "Circassia," in favour of the horizontal tandem arrangement, a machine of this description was fitted up for the New South Wales Government, at the Glebe Island Abbatoir, Sydney, in 1882, and at the official trial in August and September of the same year, some remarkably good results were obtained. The machine consisted of one steam cylinder 27in. diameter, driving two air compressors, each 24in diameter, and in connection with one expander 25·5in. diameter, all of 3ft. stroke.

The following is an extract of the log from Mr. Coleman's paper:—"Steam pressure 76lbs., cut-off 9in., running 60 revolutions with cooling water at 61° Fahr., cutting off at 22·5in. in the expander, the air pressure was 37lbs., and entering the expander at 41° Fahr. from the drying pipes, the final discharge registered −103° Fahr., the average of the room of 84,000 cubic feet capacity, being 1·5° Fahr."

In January 1885, the Bell-Coleman Mechanical Refrigeration Company was transferred to the Haslam Foundry and Engineering Company, and this firm now possesses the right of the combined patents.

During the few years of the Bell-Coleman Company's existence they had constructed in all 106 machines, ranging from 3,000 to 130,000 cubic feet delivery per hour, and had fitted at that time some of the finest vessels afloat, including the "City of Rome."

We now come to the period of the combined Haslam Bell-Coleman machine, a diagram of which is given on Plate I., Fig. 1. The arrangement is in general similar to the Bell-Coleman machine, in so far as the position of the cylinders, and shape of the soleplate are concerned. The compressor C shown is that known as the Haslam, the cylinder and valves in each cover being encased by a water jacket; the inlet and discharge valves M and N respectively, are shown in detail by Figs. 2 and 3. The inside portion of the cylinder covers are of phosphor bronze securely jointed to the cast-iron cover, and the water circulating as shown at W on Figs. 2 and 3, carries off the heat generated by compression.

Figure 2 is a section of the inlet valve, which together with seat and cap are of phosphor bronze, a steel spindle being screwed and riveted into the crown of the valve, and passing outside the cover is fitted with a collar inside the guard G; this, striking the rubber buffer I, cushions the valve at each lift, the steel spring ensuring a quick recoil.

Figure 3 is a section of the discharge valve, which is completely enclosed within the cover, and is also of phosphor bronze, but the seat and guide are in separate parts, the tube of larger diameter to admit the spring being placed inside as shown. A small buffer spring is also fitted into the cap, and on closing the outside cover O the setting up pin P is screwed against the metal disc shown in recess, thus retaining the valve seating in position, and by forming a thrust for the spring relieving the cap of the concussion of the valve. The compressor, as will be seen by Fig. 1, is fitted immediately over the water cooler DD, which is in form and construction similar to an ordinary surface condenser, the compressed air passing through the tubes and the cooling water circulating around them. The cold water enters at J from the pump and circulating throughout the cooler rises by the pipe K into the compressor jacket where circulating throughout the cylinder and valve casings it finally overflows by the pipe L. The air drawn from the cold room H by the pipe B is compressed into the tubes of the cooler where it is reduced in temperature to that of the circulating water, then passing by the pipe E traverses the drying pipes DP, as already described for the Bell-Coleman machine.

On Plate II., Fig. 2, these drying pipes are shown in section, and are generally placed in that part of the chamber where the temperature is not required below 35°. The bottom tubes of the apparatus are of larger size than the upper ones, so that in the event of extra cold return air being passed through the trunk A and circulating around the tubes before entering the pipe B on its way to the compressor, they are not so liable to choke up owing to the freezing of the water or moisture therein deposited, and which is blown off through suitable cocks at the bottom of chambers 1 and 2 in the drying pipes.

Plate 2 shows an installation fitted for ships' provisions on the same principle as Plate 1, the machine in this case is much too large for the room, but allowance was made at the time for extension. The cold air on leaving the expander Fig. 1 passes into the ice box containing 12 circular buckets having a total capacity of 4 cwt. of ice; then it passes by the trunk G into the meat room returning by the trunk A as indicated by the arrows. Before returning to the compressor it is made to circulate through the vegetable and wine rooms, as also shown by the arrows, but in the event of these rooms being sufficiently cooled, a cross trunk is shown direct to the drying pipes from the vegetable room connection, and all that is necessary is to open the slide communicating with this trunk and close all others both in vegetable and wine rooms, thereby directing the air on the meat room only.

Sectional arrangements of wine and vegetable racks are shown on Fig. 2 and a multitubular vessel of galvanised iron for cooling fresh water stands in a corner of the vegetable room connected by pipes to a tank on the upper deck and to the ship's pantry, the pressure from the tank supplying the pantry with cold water. The insulation of these rooms is effected by 4in. of wood and 8in. of charcoal, making a total of 12in.

Plate 3, Figs. 1 and 2, shows a plan and part section of a combined cargo and ship's provision rooms. This ship, besides a capacity for 8,000 carcases of mutton in the meat holds, has well arranged rooms to carry provisions for a very large number of passengers. The machine is of the compound duplex type of 60,000 cubic feet per hour delivery, is fitted in a recess over the tunnel aft the main engines of the ship, and in longitudinal

section is of the same type as shown by Fig. 1, Plate 1, and elevation as Plate 17. The drying pipes in this case are a double set, placed in the athwart-ship meat rooms and well insulated to prevent the access of any but return air. A water tower is fitted in a recess of the bulkhead as shown on plan connecting the cooler to drying pipes, the spray of water being used to cool and purify the compressed air when required; a ball trap being fitted in connection to carry off the surplus water from the tower.

When at sea the provision rooms are entered from the handing room by a hatch on the 'tween deck. The handing room has no cold air inlet, but contains a tank for salt meat, and the fresh water cooler is built in between the wine and vegetable rooms having slides to regulate the inlet of air.

A special room for the carriage of fruit is arranged on the 'tween deck as shown in part section on Fig. 2, and it may be interesting to note that this ship (the S.S. "Oceana,") brought the first general cargo of fruit to the amount of 500 tons from Australia to London. A complete set of diagrams taken from this machine are shown on Plate 4, and a half set taken when uncoupled, and working on one side only are shown on Plate 5.

The diagrams and log shown on Plate 6 were obtained through the courtesy of Mr. W. H. Northcote, of the Marine Institute, London. This machine is single acting in both compressor and expander, and like other machines of its time was not at all prepossessing in appearance, yet the results obtained as shown by the figures are remarkably good considering the high temperature of cooling water.

One of Messrs. J. & E. Hall's cold air machines on the surface cooling principle is shown on Plate 7 by a double compound duplex machine, as fitted on board the S.S. "Hawkes Bay" trading to New Zealand. This machine is complete on each side, having two pairs of tandem compound steam cylinders with surface condenser common to both, each fitted with a separate set of pumps in the centre of the soleplate worked by a drag link attached to each cross-head pin, the crank shafts being separate and the flywheels close together, and when required a drag bolt connects the wheels forming the double machine.

The cylinders arranged in line from the crank shaft respectively are low and high pressure steam, air compressor and expander, the compressors used by this firm being worked by ordinary slide valves, held by them to be more simple and requiring less attention.

The compressed air enters the water cooler as usual, but in in place of an intercharger or drying pipes, a very simple and much cheaper contrivance for drying the air is fitted at the back end of the soleplate immediately adjoining the cooler and attached beneath the expansion cylinder.

This apparatus called a moisture abstractor, is of cast-iron, cylindrical in form, placed vertically; a tangential pipe connects to the cooler and admits the cooled air, the circumferential motion in the abstractor causing the moisture held in mechanical suspension to be precipitated on the circular surface whence it trickles to an automatic float valve at the bottom, the dried air rising from the centre passes into the expander, in which it expands and is discharged as already described. The smaller machines made by Messrs. Hall have their three cylinders arranged alongside of one another, as shown on Plate 16.

A machine of this class known as the No. 9, is fitted on a sailing ship trading to the River Plate, and having a cargo capacity of 45,000 cubic feet.

This machine delivers 50,000 cubic feet of air at 100 revolutions, and while on a return voyage in July last the following temperatures were obtained, the revolutions being 78, and indicating 95 horse-power :—

Hours working per day 24 hours.	Temperatures.		
	Sea water.	Snow-box.	Holds.
8 hours.	40° F.	—108° F.	3° F.
8 ,,	50 ,,	—100 ,,	5 ,,
12 ,,	68 ,,	—87 ,,	5 ,,
16 ,,	75 ,,	—82 ,,	5 ,,
18 ,,	82 ,,	—78 ,,	4 ,,
16 ,,	77 ,,	—77 ,,	5 ,,
12 ,,	68 ,,	—85 ,,	7 ,,
12 ,,	62 ,,	—92 ,,	7 ,,
8½ ,,	62 ,,	—93 ,,	7 ,,

Among the earliest cold air machines of modern date are those on Mr. T. B. Lightfoot's patent, and manufactured by the Linde British Refrigerating Company. These machines are on the surface cooling principle, the inlet and discharge from the compressor are regulated by circular slide valves worked direct from the crank shaft by eccentrics, as shown by Figs. 1 and 2 on Plate 8. The compressed air is cooled in a metallic chamber in the soleplate, containing a series of tubes arranged so that the circulating water passes through them, the compressed air in contact with the exterior surfaces of the tubes, and precipitating the moisture held in mechanical suspension, the dried air enters a single or double-acting expander, also fitted with circular valves, where after developing power by expansion it is discharged. These machines are fully described in a paper read by Mr. Lightfoot before the Society of Engineers, in May, 1887. A machine of this type on the compressed duplex arrangement as Fig. 2 having 2 steam cylinders, 2 compressors, and 2 double-acting expanders, delivering 180,000 cubic feet per hour, is fitted on board the S.S. "Elginshire" for the carriage of 60,000 carcases of mutton, in the New Zealand trade, and this vessel is now on her homeward voyage with the first cargo.

One of the most unique cold air machines of modern date is that shown on Plate 15, made by Mr. B. Goodfellow, of Hyde. The compressor is water-jacketed, the inlet and delivery of air being effected by a series of drilled holes perforating the inner covers, regulated by circular flap valves on the principle of an ordinary air pump of a steam condenser.

The valves of the expander are of the Corliss type, the discharge air leaving by the bottom valves direct into the snow box.

In this machine Mr. Goodfellow dispenses with the drying apparatus, having increased the water-cooling surface to such an extent as to render the drying process superfluous.

While the cold air machine for some years after its production by Messrs. Bell-Coleman enjoyed a monopoly in transporting frozen meats from countries beyond the equator, the system represented by the anhydrous ammonia machine had many supporters in the comparatively short run to and from the

United States, and the adoption of this system for the swift Atlantic liners has been general.

It is true the temperatures required on this run are not low, in fact are maintained very little below freezing point as the following extract, taken recently from the log of the "City of Paris," will show. This vessel was fitted with a Kilbourn machine as shown on Plate 9, as was also the "Servia" and "City of New York."

Temperature of Rooms.				Temperature of Brine.		Temperature of Water.		Pressure Gauges.			Medium running
No. 2 Hold	No. 3 Hold	No. 4 Hold	Provision Room	Outgoing	Returning	Incoming	Discharge	Condenser	Refrigerator	Brine Pump	Hours.
28°	28°	28°	29°	19°	22°	50°	54°	120lb	34lb.	36lb.	24

An elaborate plant was also fitted on the White Star Liners "Majestic" and "Teutonic" by the Linde British Refrigerating Company, comprising 2 machines on each ship, the cooling being effected by Blackman propellers, which circulate the air through trunks from the refrigerator to the meat holds.

It was hitherto considered almost an impossibility that the ammonia and other chemical machines would ever cross the equator for large cargoes in competition with the cold-air machines, yet for some time back ships have been trading to the River Plate fitted with ammonia and carbonic anhydride machines, carrying large cargoes to this country. Take for instance, the S.S. "Hippomenes," trading from Liverpool to River Plate; this vessel is fitted with a Kilbourn machine, as shown on Plate 9, having two single-acting compressor pumps coupled direct to a 5 horse-power vertical engine, having a cylinder 7⅛in. diameter by 12in. stroke, running 100 revolutions per minute; attached to the compressor is a coil condenser and refrigerator, fitted with lap-welded iron coils, enclosed by steel casings. Two Worthington steam pumps are used, one for circulating the cold water through the condenser, the other for circulating the brine through the pipes in the holds.

The meat holds have a capacity of 43,900 cubic feet, and carry 20,000 carcases of mutton, and an extract from the log in the

run from Monte Video to St. Vincent shows the sea water varied from 73° to 84° for the condenser, yet the temperature in the holds was maintained at 20°, the pressure in the condenser averaging 168lbs., the brine varying from 14° to 18°, the machine averaging 105 revolutions.

Similar successes have been obtained by the Carbonic Anhydride machine, as shown on Plate 10, manufactured by Messrs. J. & E. Hall. This is one of the most compact machines made for refrigerating purposes, occupying a very small space for the power developed.

It is constructed on Windhausen's patent, and consists of high and low pressure steam cylinders arranged with the steam surface condenser between, in the centre of the soleplate, the tail rod of each steam piston connecting to a carbonic anhydride compressor. The coolers for the condensation of the gas, formed of copper coils, without joint, are fixed in the bed of the machine. A glance at the vapour tension diagram on Plate 11 will serve to show the great pressure and corresponding strength required of this machine. There is however, no difficulty in obtaining an ample margin of strength, for the quantity of gas circulated being small the pipes and parts of machine are of very small bore. By means of a coupling shown on the tail rod, each compressor can be disconnected, and the whole arrangement, with the double sets of coolers and refrigerators, forms two entirely independent machines.

The coils of the refrigerator are of wrought iron, made without joints, and contained in a wrought iron casing, in which the brine circulates.

The action of these machines is precisely the same as that of ammonia machines. The refrigerating effect is transmitted to the holds by the circulation of the cooled brine through pipes fixed in the top of the meat holds. The compressors in these machines are remarkable, being made of forged steel, and bored out of the solid, indeed, no parts subject to the pressure of the gas are made of cast iron.

The machine described above indicates 65 horse-power, and is sufficient to refrigerate a space to carry 50,000 carcases of mutton.

STORES.

It may now be interesting to note a few particulars of the stores, for the preparation and reception of the cargoes. In point of detail there is little or no difference beyond the shape of the building, and the capacity of both machine and rooms.

In the construction of cold rooms, on shore, a concrete or asphalt floor is first laid down, and over this 1¼in. planks, well coated with a preservative, are laid, the flooring joists being placed upon these crosswise and secured; the spaces are then filled with charcoal (flake being the best), and two thicknesses of 2in. T. & G. flooring laid over the whole and secured. The walls are of similar construction, but between the two inner linings of 1¼in. thick a specially prepared paper is placed to increase the efficiency, and the exterior wall is also covered with 2in. planking; strips of felt are placed between the lining and upright, the roof being finished in the same way.

The first store constructed in Britain for commercial purposes was fitted in 1882, by the East and West India Dock Company, London, on board an old hulk called the "Seawitch," which was fitted with a Haslam machine, having a capacity of about 40,000 cubic feet of air delivery per hour.

A few months later the Mersey Docks and Harbour Board completed an installation at Birkenhead for the chilling of meat in connection with the Woodside Lairage, being the first chilling room erected in the kingdom; this was also fitted with a Haslam machine, delivering 40,000 cubic feet of air per hour.

These stores consist of four cooling rooms, having a capacity of 60,000 cubic feet, and hanging room for 2,000 sides of beef. The carcases are conveyed from the slaughter-house to the chilling rooms by means of overhead rails, connecting by switches to the various chambers as required. A machine delivering 50,000 cubic feet per hour was put down by Mr. Goodfellow, of Hyde, to the order of this enterprising Board, in connection with extended rooms, in about 1884, and subsequently these chilling rooms were still further enlarged in 1887, and a machine on the ammonia system was put down by the Linde British Refrigerating Company, similar to that shown on Plate 12. A vapour tension diagram shown on Plate 13,

indicates the pressure and temperature required to liquify anhydrous ammonia.

In the beginning of August of the same year the New Zealand Refrigerating Company opened their works at Burnside, near Dunedin, in Otago, New Zealand, and this was the first meat freezing installation erected for export in that colony; as prior to this the carcases were frozen on board the ship in special rooms before storing in the holds.

The buildings at Burnside consisted of slaughter-house, cooling and freezing rooms, and store for carcases when ready for shipment. The machinery was supplied by Messrs. Haslam, having a capacity of 60,000 feet of air per hour, and consisted of one steam cylinder, two compressors, and one expander, indicating about 70 horse-power, and at the official trial the cold air registered from $-75°$ to $-80°$ F. These works were capable of freezing 300 carcases per day, and since that time the export of frozen meat from New Zealand to London has been the largest of our colonies; freezing stores and abbatoirs are now being erected at all the important centres of the country, as Invercargill, Christchurch, Timaru, Oamaru and Wellington, and also a very extensive plant for the North British and Hawkes Bay Freezing Company, at Napier, where Messrs. J. & E. Hall have fitted up a machine of the type shown on Plate 10, with all the latest and most modern appliances on their new system of radiation. And in Australia at Melbourne, Sydney, Brisbane and Rockhampton, large works are erected for the exportation of frozen produce.

About the same time the Burnside Works were opened in New Zealand, the River Plate Fresh Meat Company opened a similar but more extensive plant, also on the Haslam cold-air system, at Campana, near Buenos Ayres, South America, to which was added subsequently two other machines of the same class, increasing the storage capacity to 50,000 carcases, and freezing 1,300 sheep per day, with a consumption of about 13 tons of coal.

Early in 1890 further additions were made to this already large plant, by a machine on the ammonia system manufactured and erected by the Kilbourn Company, of Liverpool, to work on four rooms, having a total capacity of 94,100 carcases of sheep.

This machine comprises a horizontal compound tandem surface condensing engine, geared 2 to 1, to 2 horizontal ammonia compressors running 45 revolutions per minute. A wrot iron tank contains two tubular ammonia condensers and two strong wood tanks contain two tubular refrigerators fitted in steel shells; there are four pair of vertical double acting pumps driven by gearing and belting; two for brine circulation and two for cooling water to the condensers, and one 8 horse-power auxiliary vertical engine for working the brine pumps when the temperature is so low that the machine can be stopped. By permission from the Kilbourn Refrigerating Company the following extracts taken from letters extending over a period of eight months received by them from their representative who fitted up the plant at Campana, may be interesting as showing the method of working this system at the export stores. The machinery was started on the 6th April, 1890, and on the 20th May following he writes :—

"The sheep killed on Monday are hung in the freezing room " during the afternoon, and after 22 hours freezing are taken " out and packed in the deposit chamber to make room for the " second day's killing, and so on for six days, Saturday's sheep " being taken out on Sunday, when the machine is stopped for " cleaning until Monday mid-day when the week's work begins " again.

"At the end of 24 hours working the temperature in the " freezing room varies from 9° to 12°, the ingoing brine being " about −5° and the return brine −2° to −3°.

"On the sheep being taken out the temperature falls rapidly " to −6° and −7°, and when the fresh killed sheep are put in " the thermometer rises to about 25°, when it gradually falls " until in 23 or 24 hours it is again at −5°. On two occasions " when the sheep were being taken out the thermometer has " been at 0°, the ingoing brine −16° and the return −13·5°. " At this temperature I have stopped the machine for three or " four hours."

In another letter he says :—

"In charging the machine I used 17 drums of ammonia " which seems sufficient for the next 12 months, as the gauges " do not show any loss. The two freezing rooms and three

" deposit chambers have been in constant use since completion, " freezing 1,700 sheep per day. . . . We have had 36,000 " sheep in the deposit chamber at one time, the temperature being " easily maintained at from 9° to 10°. The coal consumption " of this plant, including a dynamo for lighting the rooms and " two blowing fans, is 3·5 tons per 24 hours, and the cooling " water during the hot season ranges from 85° to 90°."

Messrs. Eastman, Limited, have a cold store at Dublin having a capacity for 2,500 carcases, representing a total of 6,285 cubic feet.

The machine for this work is a single compressor, Kilbourn type, driven by a 4-horse-power Otto gas engine, the ammonia condenser is vertical with upright iron shell, and the liquid ammonia is stored in a reservoir and expanded direct into the pipes suspended from the ceilings of the cold rooms, thus dispensing with the brine tank.

At the present time there are many large stores for the reception of frozen meat in London, among the earliest being those in the West India and Victoria docks (particulars of which are given by Col. Martindale in the discussion on Mr. Lightfoot's paper read before the Institute of Mechanical Engineers in 1886), and the vaults below Smithfield market, where 60,000 carcases can be packed away.

Connected to the latter store are four Haslam machines having a total delivery of 240,000 cubic feet. Messrs. Nelson Bros. have also an extensive cold storage beneath the Cannon Street Railway Station, which is elaborately fitted with every modern convenience for the trade in frozen meat.

In 1886 the City of Glasgow Corporation erected extensive chilling rooms in connection with the abbatoirs at York Hill Wharf. The plant consists of a Haslam compound duplicate surface condensing machine of 110,000 cubic feet delivery per hour. The chilling rooms are of similar construction to those at Woodside, Birkenhead, with overhead rails, and every convenience for hanging 600 sides of beef, the total capacity of the rooms being 45,000 cubic feet.

A similar installation was laid down at the Deptford foreign cattle market by the City of London Corporation in 1889. An

existing building adjoining the abbatoirs, having a frontage on the Thames was used for the purpose. There are four chill rooms, each fitted with rails overhead connected to the abbatoir by switches to carry the beef; each room having a capacity of 7,700 cubic feet, and hanging room for 100 sides of beef, making a total space for 400 sides. The machine used for this work is a Haslam compound tandem type, delivering 70,000 cubic feet per hour, but in May last this large plant was still further extended, by adding three additional rooms and substituting a larger machine by the same firm, having a cubic delivery of 150,000 feet, on the compound duplex system, of the type similar to that shown on Plates 8 and 17.

Probably the largest cold air installation in London at the present time, is that at the No. 29 shed, Victoria Dock, belonging to the London and India Docks Joint Committee, and through the courtesy of the Company's engineer, Mr. Carr, the author was enabled to visit this extensive plant in January last. The machinery is on the cold air system, by Messrs. Haslam, and has a total capacity of 280,000 cubic feet delivery per hour, working on rooms having a total capacity for 165,000 carcases.

This plant is divided into two sections, the first consisting of a compound duplicate machine of 110,000 cubic feet, delivering to rooms having capacity for 60,000 carcases, and the second and largest section consisting also of a compound duplicate machine of 170,000 cubic feet delivery, to rooms having a total capacity for 105,000 carcases, part of these rooms being of recent construction, and further extensions in prospective. The two sections are divided by a covered way having two lines of rails, and adjacent to the quay. The cold rooms are placed in tiers, one above the other, and shoots are provided for discharging the carcases, and a novel hydraulic lift terminating on a curve, to pitch the carcases into the rooms, is so arranged that on reaching the top, a projecting lever is caught by the lift, and opens a hanging door, when the carriage tilting on the curve, pitches the carcases into the room, and again descending, closes the door; this apparatus is quite automatic and several are fitted in connection with this plant.

The 170,000 cubic feet machine is of the latest type, fitted with every modern improvement, and is on the surface cooling

principle, having high and low pressure steam cylinders, two air compressors of the Haslam type, and two air expanders of the Bell-Coleman type; a set of diagrams are shown on Plate 14 with log, taken when running only 5 hours per day of 24 hours, at an average coal consumption of 2·012lbs. per indicated horse-power per hour, including a 12 horse-power electric engine and dynamo. The cold rooms are lighted by electricity, and every convenience for the quick storage and discharge of carcases has been adopted.

One of the largest cold stores in Lancashire is that of Messrs. Eastman, Derby Road, Liverpool. This plant has a capacity for storing 120,000 carcases in addition to freezing 15 tons of ice per 24 hours. The rooms have a cubic capacity of about 300,000 feet, arranged in tiers one above the other, accessible by hydraulic lifts.

The machinery employed is of the Kilbourn Co.'s make, and comprises two sets compound tandem surface condensing engines, driving two ammonia compressor pumps. The steam cylinders are high and low pressure, 10½in. and 21in. diameter respectively, and 36in. stroke, making 90 revolutions and geared to the compressors 2 to 1, the wheels running in oil. The compressors are 11in. diameter by 30in. stroke, making 45 revolutions. The plant is duplex throughout, and the total horse-power indicated is 106·5 average in five week's running, at a consumption of 2·2lbs. of coal per indicated horse-power per hour. This plant adjoins the London and North Western Railway sidings, having every convenience for discharging carcases.

Messrs. J. & E. Hall, have just completed, at Napier, New Zealand, the erection and testing of a large plant for freezing 500 sheep per day by their new method, which differs essentially from previous methods. This system does not depend, as in all other cases, upon the convection of heat from the meat by the agency of cold air, which is the method hitherto adopted where cold-air machines are used, or where cold pipes are placed in the roof of the freezing chamber, but they subject the meat to the direct action of hollow metal walls, through which brine circulates at about zero, thus abstracting the heat from the meat by radiation. The whole system consists in several of these

parallel walls set at a short distance apart, and between them the carcases to be frozen are passed.

The carcases are hung on hooks, which are connected together forming an endless chain which is moved forward by power. The sheep after being killed and cleaned are hung on these hooks in the slaughter house, and then moved forward automatically through the hanging room to the freezing room, the hanging room being of sufficient length to ensure their getting rid of the animal heat before they pass between the freezing walls. The length of these are such that the carcases are subject to the freezing process a sufficient length of time, when they automatically enter the bagging room where the bags are put on, and they are handled for the first time since hanging in the slaughter house. A continuous lift now raises them to the rooms above, where they are stored ready for shipment.

The remainder of the machinery consists of one of J. & E. Hall's carbonic anhydride machines, as shown on Plate 10, which maintains the low temperature of brine in the walls. By this method the meat is very rapidly and thoroughly frozen, and it is evident that the amount of labour is reduced to a minimum.

The application of refrigerating machinery for ice-making purposes has long been the dream of inventors, and the success attained in this branch of refrigeration is undoubtedly due to the ammonia machine, which together with the carbonic anhydride system is well adapted for this purpose, by reason of the facility with which an even temperature is transmitted and maintained. The usual and most effective method of producing good clear ice is by means of cold brine circulating around iron moulds containing the water to be frozen, and on this principle the Linde British Refrigerating Company have probably the largest plant in the kingdom, capable of turning out 150 tons per day, particulars of which may be seen in the *Engineer* of May 16 and 30, 1890. The machinery for this branch of refrigeration on a large scale would supply ample material for a separate paper, and the few notes intended for our present subject are brought forward to show what was done under extreme conditions during the Soudan campaign of 1884-5 by the cold air machine at Souakim. Three vessels were employed at this port

by H.M. Government in making ice, the S.S's. "Amethyst, "Latharna," and hospital ship "Bulimba," and each of these ships were fitted with a Haslam 40,000 cubic feet machine, having a steam cylinder 18in. diameter, air compressor 22in. diameter, and expander 17in. diameter, all 22in. stroke. The "Bulimba" was fitted in the 'tween decks with meat rooms of 40 tons capacity, ice-making room, and a store capable of holding a reserve of 15 tons. The ice room was fitted up as shown in part by Figs. 7 and 7A on Plate I., the buckets used being of galvanized iron, circular in form, and having a conical centre tube rivetted to the bottom thus exposing a larger surface to the cold air, and to prevent unequal expansion a loose cover fitted on each one as shown on Fig. 7.

The cold air forced by the machine through circular apertures in the trunk G passed up through the centre tube of each bucket and permeated the room, the heat and vapour from the water being drawn away through the trunk A. Special arrangements were also made on this ship to distil the water for ice-making purposes, which was pumped into a tank on the bridge deck, and connected to the refrigerator engine room by a galvanised iron pipe terminating in a length of rubber hose and fitted with a nozzle cock.

The hose was passed into the ice room through a square aperture unplugged for this purpose, and by this means the buckets were easily and quickly filled, the distilled water entering at from 90° to 110°.

During the month of June, 1885, the temperature on deck registered from 100° to 106° in the shade, and that under double awnings, the refrigerator engine room standing at from 125° to 130° with bulkheads down and hatches open, the quantity of ice given out to troops and ships averaged 2 tons per day, working the machine 18 out of 24 hours; this included keeping provisions, fruit, &c., for the hospital.

The steam averaged 60lbs., cutting off at ¼ stroke and running 90 revolutions, exhausting on the main engine condenser and indicating about 90 horse-power: the air pressure averaged 49lbs. at 10in. cut off in the expander. The cooling water registered 94° and snow box averaged −25°, the ice room

varying from 12° to 15°. The difficulty experienced was after the water was cooled to freezing point the bottom buckets congealed too rapidly and the surface of the block burst upwards forcing off the cover, while the ice in the top buckets was always found to be less opaque owing to the higher temperature and consequently slower process. To obviate this, when partially frozen the buckets were changed and the volume of air checked.

Daily at 5 a.m. the buckets of ice were taken out and ranged upside down along the 'tween deck until thawed by the heat, the ice dropped from the moulds, and at six o'clock the boats coming alongside obtained their allowance on sight of order, some of the precious article being wrapped in blankets and transported to the extreme limits of the camp by camels, about 70 per cent. reaching its destination.

Coming now to the present time the great improvements made in the ammonia and carbonic anhydride machines, both in the compressors, condensers, and refrigerators, or vaporisers, have been such as to place them on the highest scale of efficiency, and as has already been shown these machines now import cargos from countries beyond the equator that a few years ago would have been considered madness to attempt; and more than this, it is held by the makers of these machines that the cargoes are imported at less than half the cost of those brought by the cold air machines.

No doubt there are some disadvantages attending the distribution of brine pipes along the ceilings of the holds, owing to the risk of damage on the outward voyage, by the storage of general cargo, but in the case of the "Majestic" and "Teutonic" this objection has been entirely removed by substituting ordinary trunks through which the air is circulated over the cargo from the refrigerator pipes by Blackman propellors; this of course entails the use of extra plant, and the question arises why is it not as economical to employ a machine embodying all these parts, to ensure simplicity and ultimately the same results in economy? With the cold dry-air machine temperatures are reduced as low as 110°, and in the case of a machine made by Messrs. Hall, of the type shown on Plate 7, a reduction of 124° below zero was obtained; such results are not possible with

either the ammonia or carbonic anhydride machine. But on the other hand, temperatures below zero are not necessary for the importation of frozen meat, and as shown by the Kilbourn machine, recently erected at Campana, temperatures ranging from 10° to 5° were effectually maintained on a comparatively small consumption of fuel.

In the carbonic anhydride machine, as shown on Plate 10, we have a most compact arrangement, and great power of refrigeration in a comparatively small space, a cold-air machine having the same refrigerating power occupying double the space.

Another instance of the efficiency of the chemical machine, in this case on the direct expansion system, is demonstrated at Messrs. Eastman's Stores, Dublin, and already noticed under cold stores. There are two insulated rooms and a large show case, having a total capacity for 150 tons of meat, and this work is effected by a 4 horse-power Otto gas engine, which drives, by a belt, a small Kilbourn machine, having a single-acting ammonia compressor.

With regard to the commercial value of refrigerating machinery, this is based upon the imports brought into the country by means of refrigeration, whether cooled, chilled, or frozen, since the year 1880 inclusive, and the following returns taken from figures obtained from the Statistical Department and by the courtesy of the New Zealand Loan and Mercantile Agency Company, will serve to show the value of this branch of engineering to the nation. (See following tables.)

It will be seen by these figures that the total value of imports from all sources in the year 1880 amounted to nearly two millions, and in the year 1891 to nearly seven and a half millions, making a total increase in eleven years of five and a half millions, and the total value for the eleven years inclusive to over forty-four and a half millions sterling, or 275 per cent.

Although the frozen meat trade was not inaugurated until 1879 when Mr. Coleman brought the first cargo from New York, we must not omit the fact that ether and ammonia machines had been bringing chilled cargoes before that date, but the machines were not so efficient as those of to-day, and the results were consequently not always satisfactory. The cold-air machine was the means of opening up the frozen meat trade

IMPORTATIONS OF REFRIGERATED PRODUCE INTO THE UNITED KINGDOM, FROM 1880 TO 1891 INCLUSIVE.

1880.

FROM	BEEF.			MUTTON.			APPLES.			BUTTER.			CHEESE.			TOTAL VALUE.
	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	Bush.	Average per bushel.	£	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	
		d.			*d.*						*d.*			*d.*		£
North Russia..	....		....	....		....	....		....	....		....	....		....	
Australia	359	4·625	775	214	4·750	475	....		....	4,595	7·087	14,903	963	6·700	3,011	19,164
Canada	1,628	4·573	3,509	....		....	....		....	....		....	....		....	3,509
United States.	724,272	5·566	1,881,469	....		....	....		....	....		....	....		....	1,881,469
River Plate...	....		....	....		....	....		....	....		....	....		....	....
Falkland Isles.	....		....	....		....	....		....	....		....	....		....	....
Totals	726,259		1,885,753	214		475				4,595		14,903	963		3.011	1,904,142

1881.

North Russia..	....		....	....		....	....		....	....		....	....		....	....
Australia	2,495	4·417	5,143	9,254	4·5	19,434	....		....	13,807	8·000	51,150	1,229	5·066	2,906	78,633
Canada	60,295	6·178	173,846	....		....	....		....	....		....	....		....	173,846
United States.	747,785	5·667	1,977,640	....		....	....		....	....		....	....		....	1,977,640
River Plate ..	....		....	....		....	....		....	....		....	....		....	....
Falkland Isles.	....		....	....		....	....		....	....		....	....		....	....
Totals	810,575		2,156,629	9,254		19,434				13,807		51,150	1,229		2,906	2,230,119

1882.

North Russia .	....		....	....		....	....		....	....		....	....		....	....
Australasia ..	1,665	4·660	3,621	37,283	5·411	94,240	10	16/-	8	5,436	10·929	27,727	175	6·70	547	126,143
Canada	23	5·590	60	30	5·071	71	....		....	....		....	....		....	131
United States.	446,778	5·958	1,242,400	29,062	6·114	82,921	....		....	....		....	....		....	1,325,321
River Plate ..	....		....	....		....	....		....	....		....	....		....	....
Falkland Isles.	....		....	....		....	....		....	....		....	....		....	....
Totals	448,466		1,246,081	66,375		177,232	10		8	5,436		27,727	175		547	1,451,595

IMPORTATIONS OF REFRIGERATED PRODUCE INTO THE UNITED KINGDOM, FROM 1880 TO 1891 INCLUSIVE.

1883.

FROM	BEEF.			MUTTON.			APPLES.			BUTTER.			CHEESE.			TOTAL VALUE.
	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	Bush.	Average per bushel.	£	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	
		d.			d.						d.			d.		£
North Russia..	21,986	5·305	54,434	433	6·478	1,309	....		....	....		....	....		....	55,743
Australasia ..	1,522	5·968	4,231	103,689	4·302	291,506	2,709	7/5·57	1,011	1,127	9·117	4,795	423	5·846	1,176	302,719
Canada	33,951	5·946	94.221	224	6·409	670	....		....	....		....	....		....	94,891
United States.	730,966	6·036	2.059,007	41,398	6·200	119,639	....		....	....		....	....		....	2,178,646
River Plate ..	....		...	3,571	6·000	10,000	....		....	....		....	....		....	10,000
Falkland Isles	....		. .	....		....	....		....	....		....	....		....	....
Totals ...	788,425		2,211,893	149,315		423,124	2,709		1,011	1,127		4,795	423		1,176	2,641,999

1884.

North Russia ..	31,707	4·896	72,449	900	4·735	1,989	....		....	....		....	....		....	74,438
Australasia ..	2,754	5·258	6,758	304,124	5·797	822,842	246	8/6·5	105	4,540	9·121	19,326	2,813	6·021	7,905	856,936
Canada	23,606	5·986	65.953	69	4·968	160	....		....	....		....	....		....	66,113
United States .	811,644	5·826	2,206,704	32,229	6·170	92,802	....		....	....		....	....		....	2,299,506
River Plate ..	500	4·800	1,120	40,230	5·227	98,136	....		....	....		....	....		.. .	99,256
Falkland Isles.	....		....	....		....	....		....	....		....	....		....	....
Totals ...	870,211		2,352,984	377,552		1,015,929	246		105	4,540		19,326	2,813		7.905	3,396,249

1885.

North Russia..																
Australia	10,398	4·479	21,738	1	4·285	2	....		....	....		....	....		....	21,740
New Zealand..	16,622	5·400	41,888	337,587	5·310	836,558	4	15/-	3	1,474	8·779	6,039	4,067	5·086	9,653	894,141
Canada	17,736	5·708	47,250	519	5·165	1,252	....		....	....		....	....		....	48,502
United States..	854,845	5·576	2,224,158	33,244	5·940	92,155	....		. ..	....		....	....		..	2,316,313
River Plate ..	930	5·519	2,396	112,223	5·530	289,625	....		....	....		....	....		....	292,021
Falkland Isles.	....		....	....		....	....		....	....		....	....		....	....
Totals	900,531		2,337,430	483,574		1,219,592	4		3	1,474		6,039	4,067		9,653	3,572,717

IMPORTATIONS OF REFRIGERATED PRODUCE INTO THE UNITED KINGDOM, FROM 1880 TO 1891 INCLUSIVE.

1886.

FROM	BEEF.			MUTTON.			APPLES.			BUTTER.			CHEESE.			TOTAL VALUE.
	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	Bush.	Average per bushel.	£	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	
		d.			*d.*						*d.*			*d.*		£
North Russia..	5,754	4·491	12,060	....		....	....		....	....		....	....		....	12,060
Australasia ..	21,157	4·511	44,543	384,276	4·809	842,409	319	8/3·31	132	131	8·964	548	8	5·625	21	887,653
Canada	10.054	4·517	21,196	86	4·390	176	....		....	....		....	....		....	21,372
United States.	762,226	4·969	1,767,803	6,369	5·192	15,498	....		....	....		....	....		....	1,783,301
River Plate...	6,736	4·340	13,640	190,409	4·121	370,363	....		....	....		....	....		....	384,003
Falkland Isles.	....		.. .	17,952	4·777	40,011	....		....	....		....	....		....	40,011
Totals	805,927		1,859,242	599,092		1,268,457	319		132	131		548	8		21	3,128,400

1887.

North Russia..	2,782	3·093	4,016	....		....	....		..	....		....	....		....	4,016
Australasia ...	8,416	4·143	16,274	438,083	4·312	918,816	4,170	10/11·8	2,290	6,201	7·606	22,011	10,317	5·129	24,698	984,089
Canada	169	4·757	395	55	4·792	123	....		....	....		...	....		...	518
United States.	643,320	4·841	1,453,456	2,289	3·370	3,600	....		....	....		....	....		....	1,457,056
River Plate ..	270	3.412	430	251,273	3·774	442,597	....		....	....		....	....		....	443,027
Falkland Isles.	....		....	23,476	4·202	46,037	....		....	....		....	....		....	46,037
Totals	654,957		1,474,571	715,176		1,411,173	4,170		2,290	6,201		22,011	10,317		24,698	2,934,743

1888.

North Russia .	4,717	3·491	7,685	11	5·844	30	....		....	....		....	....		....	7,715
Australasia ..	41,354	4·467	86,223	543,117	4·356	1,104,173	29,908	10/2	15,205	25,525	8·418	100,275	26,998	5·137	64,723	1,370,599
Canada	93	4·589	199	27	3·095	39	....		....	....		....	....		....	238
United States.	784,429	4·953	1,813,382	7,157	3·002	10,027	....		....	....		....	....		....	1,823,409
River Plate ..	3,678	3·333	5,721	345,392	3·880	625,548	....		....	....		....	....		....	631,269
Falkland Isles.	....		..	....		....	....		....	....		....	....		....	....
Totals	834,271		1,913,210	895,704		1,739,817	29,908		15,205	25,525		100,275	26,998		64,723	3,833,230

IMPORTATIONS OF REFRIGERATED PRODUCE INTO THE UNITED KINGDOM, FROM 1880 TO 1891 INCLUSIVE.

1889.

FROM	BEEF.			MUTTON.			APPLES.			BUTTER.			CHEESE.			TOTAL VALUE.
	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	Bush.	Average per bushel.	£	Cwts.	Average per lb.	£	Cwts.	Average per lb.	£	
		d.			*d.*						*d.*			*d.*		£
North Russia..	....	..	..	....	....	....	....	....	....	....	....	....	....	....	....	....
Australasia ..	99,996	3·965	185,065	610,599	4·519	1,287,955	29,426	9/4·82	13,833	16,315	9·908	75,439	7,137	4·056	17,982	1,580,274
Canada	148	4·097	283	12	3·214	18	....		....	....		....	....		....	301
United States.	1,275,948	4·746	2,826,516	1,609	4·119	3,093	....		....	....		....	....		....	2,829,609
River Plate ..	8,665	3·538	14,308	395,303	4·067	750,310	....		....	....		....	....		....	764,618
Falkland Isles	....		...	....		....	....		....	....		....	....		....	....
Totals ...	1,384,757		3,026,172	1,007,523		2,041,376	29,426		13,833	16,315		75,439	7,137		17,982	5,174,802

1890.

North Russia..	12,749	3·651	21,727	1,590	4·569	3,357	....		....	....		....	....		....	35,084
Australasia ..	109,921	3·831	196,551	897,148	4·346	1,823,478	45,576	14/3·8	32,643	40,498	8·928	168,738	28,992	4·883	66,066	2,287,476
Canada	27,911	4·275	55,694	13	4·945	30	....		....	....		....	....		....	55,724
United States.	1,693,148	4·594	3,629,939	134	4·365	273	....		....	....		....	....		....	3,630,212
River Plate ..	8,933	3·610	15,425	435,084	4·050	822,486	....		....	....		....	....		....	837,911
Falkland Isles.	....		....	5,445	4·293	10,910	....		....	....		....	....		....	10,910
Totals....	1,852,662		3,919,336	1,339,414		2,660,534	45,576		32,643	40,498		168,738	28,992		66,066	6,847,317

1891.

North Russia..	8,736	4·014	16,365	918	4·796	2,055	....		....	....		....	....		....	18,420
Australia	42,914	3·514	70,373	166,115	4·248	329,525	139912	12/6·5	87,765	54,418	10·666	270,880	29,702	5·357	74,257	2,785,930
New Zealand..	106,134	3·514	174,045	897,342	4·248	1,779,085										
Canada	287	4·770	639	5	5·570	13	....		....	....		....	....		....	652
United States..	1,747,578	4·592	3,745,324	10,574	4·939	24,373	....		....	....		....	....		....	3,769,697
River Plate ..	14,485	4·563	30,850	436,358	3·884	791,011	....		....	....		....	....		....	821,861
Falkland Isles.	....		....	10,767	3·150	15,880	....		....	....		....	....		....	15,830
Totals	1,920,134		4,037,596	1,522,079		2,941,892	139912		87,765	54,418		270,880	29,702		74,257	7,412,390

with Australasia, and so rapidly had it gained pre-eminence that in 1880 both beef and mutton were brought from Australia, and in 1882 New Zealand contributed the first consignment of mutton, the River Plate Fresh Meat Company following in 1883, and since that time New Zealand has continued to send into this country the largest proportion of meat next to the United States; and that this is not likely to be reduced is shown by the proceedings at a meeting of the Dunedin Chamber of Commerce, published by the "Otago Witness" in December last, when the President, Mr. A. S. Paterson, in reviewing the exports of that Colony gave the frozen meat exported per annum as equivalent to 2,000,000 sheep, 10 per cent of which is beef, leaving 1,800,000 sheep and lambs exported from a total flock of 17,000,000 sheep, about 11 per cent., and that after feeding the population of the Colony; and yet there is an increase per annum of 633,000 sheep, or about 4 per cent. It may not be uninteresting to mention here that the New Zealand Shipping Company arranged to dispatch a vessel from New Zealand ports direct to Liverpool in February last with frozen meats and dairy produce, and on the 17th inst. this ship, the S.S. "Duke of Buckingham," arrived in Liverpool with a cargo comprising 33,708 carcases of mutton and lamb, 403 quarters of beef, 878 packages of butter, and 445 packages of cheese, all in excellent condition, the meat alone weighing 828 tons, valued at upwards of 38,646 pounds sterling. The importance of this departure to the industrial population of Lancashire cannot be over estimated, and in view of completion of the Ship Canal the development of this direct trade will be of the greatest importance to Manchester.

Of the refrigerating machinery employed in ice works, curing factories, dairies, chemical works, breweries, in cooling chocolate, and in the process of candle-making and other industries it is impossible to obtain the value for so limited a paper, but some idea may be formed of the magnitude of this industry when it is seen that about 750 cold air machines have been made in Britain since 1879, representing an aggregate of 44,000,000 cubic feet delivery per hour. Of this number Messrs. Haslam & Co. have alone constructed 400 machines equivalent to 25,000,000 cubic feet per hour.

Of the ammonia and similar machines, these are more difficult of access, but the Linde Company have produced 1,448 machines on this system, and the De La Vergne Company upwards of 500, those under the Kilbourn patents amounting to a considerable number.

The New Zealand Loan and Mercantile Agency Company in reviewing the imports for 1891, note the consignments for River Plate amounted to 1,129,571 carcases, against 1,133,682 in 1890, showing a falling off: of this amount 58,495 carcases were consigned to London, 29,000 to Cardiff, 18,360 to Glasgow, and 923,716 to Liverpool, against 1,009,035 in 1890 to the latter port.

The importation of mutton and lamb from Australasia in 1891, amounted to 2,227,463 carcases, against 1,740,215 in 1890, being an increase of 126,878, or 60 per cent. from Australia, and 360,370, or 23 per cent. from New Zealand. Importations of beef from Australia show an increase of 13,602 pieces, and from New Zealand 13,316 pieces for 1891. During 1891 stocks reached 220,000 carcases, and towards the latter part of the year, it was difficult to find storage at all, yet the tendency is to increase the size of machines, and to allot a larger portion of cargo space to the importation of refrigerated produce.

The author has endeavoured in the foregoing pages to give as much practical information as the limits of this paper will permit, drawing upon a practical experience with cold air machines, both at home and abroad, largely aided by those gentlemen and firms who have so kindly contributed by both information and the blocks of their respective machines for illustrations, for which he is much indebted; and the object of this paper will have been attained by creating a discussion and interest in a class of machinery that will one day form an important factor in the importation of refrigerated produce to the extensive docks of Manchester.

DISCUSSION.

Mr. W. J. JENKINS, in opening the discussion, remarked that he did so with great pleasure, as he was recently much interested in the description of a journey of some friends of his who returned from the West Indies in one of the Royal Mail Steamship Co.'s steamers, and who were highly satisfied with the plentiful supply of fresh meat and other luxuries they got on the voyage, chiefly owing to the efficient working of a cold-air refrigerating machine on board. The meat and fruit for the round trip were shipped in England, and carried right through the tropics and back without damage.

He had taken great interest for years in the compression of air, and in the transmission of power by its aid, and his remarks would therefore deal more particularly with the compressors. For the purposes of the discussion he had borrowed from Mr. Quicke an original set of diagrams very similar to those on Plate 4, but better in some respects. They were taken from a 110,000 cubic feet machine, by Messrs. Haslam, with a Bell-Coleman expander. The first point of interest was of course the compression curve; he had been in the habit for some years of working out the index of the curve given by the formula

$$P V^{\gamma} = \text{a constant}$$

from every diagram he could obtain, and had seldom found γ lower than 1·3, that is—

$$P V^{1.3} = \text{a constant}$$

with ordinary water-jacket cooling without injection, but having noticed the extreme care taken to make the cooling effectual, as shown on Plate 1, by the use of bronze false covers, provided with circulating spaces W, inside the ordinary end covers of the cylinder he was expecting a considerably better figure in this case. The result, however, was not so much different as might have been expected, for the index was 1·284, showing a considerable saving over the adiabatic curve for air, where the index was 1·408, but not reaching so low a figure as 1·25, which was generally taken to represent the minimum under ordinary

practical conditions. It should be noted however that the curve was not strictly regular, the index being greater for points near the toe of the diagram than for points near the top, due, of course, to the effect of the greater difference of temperature, between the air inside the cylinder and the water in the jacket, at the higher pressures and the consequent more rapid flow of heat.

It spoke well for the carefulness of the marine engineers who had charge of these machines to find that the actual clearance was not more than 1 per cent., or about $\frac{3}{32}$ of an inch. With ordinary men ashore such care was difficult to obtain, and the result of such a narrow margin for adjusting connecting-rod bearings would probably be a succession of broken covers or pistons. But even with such a very small clearance the output of the compressor was reduced 4 per cent. at least. It really seemed a pity to go to so much trouble to reduce the effect of clearance when a better result could be obtained without the addition of a single moving part, by passing the air from the clearance spaces to the suction side of the piston, immediately at the end of the stroke. He noticed that one maker used a slide valve compressor, and he would be glad if more information could be given of the details, because everyone must desire the quiet and regular action of the slide in preference to the hammering action of mushroom valves; but one great objection to the slide valve when used without the bye-passing of air, as previously explained, was the large clearance space its use involved; yet he had suggested the use of the bye-passing method some years ago to a firm making slide valve compressors, and with excellent results, for the air out of the clearance spaces on the pressure side of the piston, when passed at the end of the stroke to the suction side, increased the air there to no less than 5lbs. pressure per square inch, so that the delivery stroke began with 5lbs. instead of atmospheric pressure.

A serious defect with mushroom delivery valves, as shown on Plate 1 (Fig. 3) was the throttling of the passages, resulting in a considerable waste of power to force the air out of the cylinder. This waste had the effect of increasing the temperature of the air uselessly. The whole of the power shown by the diagrams between the dotted line and the ragged upper line of the diagram

(Plate 4) was so wasted; and though the diagrams which Mr. Jenkins had treated of were not so bad as those on Plate 4, yet they showed a waste of 4·5 indicated horse-power, which was spent in raising the temperature of the whole of the air passing through the valves by no less than 12·5 degrees F.

Theory and experience seemed to have reached a high degree of agreement in the case of these diagrams, for the temperature indicated by a point on the compression curve, where the dotted line of receiver pressure cuts it, was 258°, and adding to this the 12·5° due to waste by friction, the resulting temperature, after passing the valves, was 270·5°, or within half a degree of a thermometer placed in the air.

It was remarkable how low the power efficiency of these solidly constructed machines was. In the case under notice the power indicated in the compressor was only 68·8 per cent. of that indicated by the steam engine and the expander. This was probably owing to the difficulty of lubricating the expander and to the formation of snow on the inside of the barrel.

The weight of air delivered per hour by the expenditure of 2·5 indicated horse-power was 100lbs., and this at 2lbs. of coal per indicated horse-power per hour was equivalent to the abstraction of 667·7 units of heat per lb. of coal, or equal to the production of 4·63lbs. of ice per lb. of coal. A year or two ago Mr. Lightfoot gave an instance in which 100lbs. of air per hour was reduced from 60° above to 80° below zero F. for an expenditure of 1·8 indicated horse-power, or equal to the abstraction of 916 units of heat per lb. of coal. As the initial and final temperatures were the same in the above examples they will serve as a good comparison.

Knowing the ratio of the volume of the compressor cylinder to that of the expander it was easy to calculate the final temperature, providing, as was usually the case, the cut-off in the expander was arranged to allow the air to escape at atmospheric pressure.

Bearing in mind the facts that whatever weight of air was delivered by the compressor per revolution, the same weight of air was discharged by the expander per revolution, and that the pressure at the inlet to the compressor was the same as that at the outlet of the expander, and further, that the volume occupied

by the same weight of air, if under the same pressure, is inversely proportional to the absolute temperature, then the calculation can easily be made. For example, if the ratio of the compressor to the expander was 1·562 : 1, and the inlet temperature 60° F. (= 520° absolute) the temperature after expansion to atmospheric pressure would be :—

$$1{\cdot}562 : 1 : : 520° : 333° \text{ absolute,}$$

and 333° absolute = 460 − 333 = − 127° F.

The actual snow-box temperature by thermometer was − 81° a difference easily accounted for by slight excess of pressure in the expander to force the air out, and consequent friction and heating, also by the heat set free during the formation of ice from the moisture in the air.

The chemical machines seemed to be much more economical than the air machine, but the latter had advantages as regarded safety, for it would be highly dangerous if either the ammonia or the carbonic anhydride machine broke down during a voyage so that the gases escaped, whereas the air would hurt no one.

The reason for the greater economy was clear. With the chemical machines a great weight of cooling agent would be circulated and the temperature need not be so exceedingly low, but with air a large expenditure of power was necessary to set in motion a very small weight of air, and unless that smaller weight had a proportionately lower temperature the effect would be insignificant.

Mr. E. G. Constantine said he might mention that before the present system of dry-air refrigerating machinery was introduced, one of the earliest methods adopted was that of having a draught of cold air passed by a fan through an ice chamber into the chamber containing the meat. Each hold was fitted with two or three ice chambers.

Mr. R. J. H. Sayers asked if the author could state the actual cost per carcase, or per lb., for conveying refrigerated meat from New Zealand to England, also what it cost on arrival for storing in stores fitted with the most perfect system of machinery.

Mr. JOHN WEST (ex-President) said that this was the first paper on such a subject that had been read before the Association, and their thanks were due to the author for the able and interesting manner in which he had laid the information contained in his paper before them. He had given a useful historical sketch of the subject, from which it appeared that dry-air refrigerating machinery had had connected with it many gentlemen of great scientific attainments.

He could not quite understand what was to be inferred by the term commercial value, but what he should like to know was the cost per ton of meat for refrigerating, say from Australia to England, that was, independent of the ordinary freight charges. The importation of refrigerated meats in recent years had assumed enormous dimensions, and it was certainly interesting to them, as engineers, to know that with the forces of the engineers and chemists combined, those professions had been able to produce such good results for the benefit and well being of the community generally.

The PRESIDENT (Mr. G. B. Goodfellow) thought that the author had not given Mr. Coleman the proper credit for his inventive genius. He believed the first air machine was invented by Mr. Coleman, while he was chemist for the firm of Young & Co., for the purpose of condensing the gas which came off the paraffin scales, in order to obtain a valuable product therefrom, and which before had been lost. He lately saw some portions of this machine, and he was informed that it was one of the earlier or the earliest machine constructed on the dry-air principle. Mr. Bell, who was in the meat trade, was introduced to Mr. Coleman, and hence resulted the dry-air refrigerating machine for the preservation of meat.

Some makers in the early days made several machines, particularly those of small sizes, with vertical cylinders, and he should be glad to learn from the author if there was not great difficulty found with the ice in the expansion cylinders.

Referring to Plate 1, Fig. 5, he found the valves on the expansion cylinder shown thereon, although being accessible when snow and ice had collected in the valve boxes, were

far from being correct in construction for a cylinder of that type, and further with the port being on the side of the expansion cylinder the ice was liable to collect in the form of snow round the cylinders, and be pushed forward with the piston. If the outlet ports were put in the bottom the ice and snow would be blown through into the snow box.

As regards the De la Vergne machine, he would like to know if there was any practical advantage in the oil sealing as compared with other machines? Were better results obtained from it than from say the Linde machine, which had a horizontal compressor, and in which the oil sealing was not used?

In the fifth paragraph on page 106, it was remarked that "the air pressure was 87lbs. . . . and the final discharge registered — 108° Fahr." If that were not an error it was exceptionally good, because if — 108° was obtained at a pressure of 60lbs. it was decidedly above the average.

The author had mentioned that he (the President) in his machines had dispensed with the drying pipes, and he might add that such was the case, as after making the most careful experiments he had come to the conclusion that they were perfectly superfluous. As a matter of fact all cooling pipes were drying pipes, as they could not cool the air without drying it.

The water tower he had also dispensed with, nor did he require or thought any one else required the apparatus mentioned by Mr. Quicke as adopted by Messrs. Hall, for collecting the water out of the air, because it was quite possible, if the coolers were properly constructed, to obtain sufficient moisture out of the air to get it dry enough for the purpose.

Referring to Mr. Jenkins' remarks respecting slide valves or compression cylinders, he could not say why there should be any advantage in them. There were difficulties with compression he admitted, on account of the great heat burning the oil on the surfaces, but not having had much experience with slide valves for compression cylinders he could not say much about them. He thought however it would be difficult to keep the surfaces well and properly lubricated; even if the valves were mitred there was a tendency for them to stick. He (the President) used flat valves, and if they were not cleaned out every voyage they were liable to get clagged up.

He certainly could not help Mr. Jenkins in the query raised as to what became of the large amount of power which evidently was absorbed in the machines; but he thought it should not be beyond our mechanical genius to solve the problem.

The President concluded his remarks by pointing out the great care requisite to efficiently work refrigerating machinery and the necessity of having competent engineers to look after it, without which good results would not be obtained.

Mr. D. FULTON thought that the President was in error in giving Mr. Coleman the credit of being the first inventor of the dry-air refrigerating machine, as he believed that honour was due to Mr. Kirke, who made a machine so early as 1860, although probably the former gentleman was the first to bring the machine to a commercial success. He might add that about 18 years ago he was in intimate connection with Mr. Kirke, and at that time he made for him a full set of working drawings for air pressing machinery and a set of ice cylinders, for a firm in Glasgow, which ultimately failed.

Mr. QUICKE, in reply, thanked Mr. Jenkins for his valuable and interesting contribution to the discussion. With regard to the slide valve in the air compressors, this was a speciality with Messrs. Hall's machines, and the very excellent results obtained from them demonstrated its efficiency, as in the larger machines as low as — 120° F. was often obtained, and in one instance —124° F., at an air pressure not exceeding 60lbs.

Referring to the credit given the late Mr. J. J. Coleman for his inventive genius, alluded to by the President, the paper bore ample testimony to the value of the Bell-Coleman machine, which had introduced a trade which was rapidly increasing to enormous proportions. Nevertheless, the fact must not be overlooked that such a result was largely due to the efforts and experiments made by Doctors Gorrie, Siemens and Kirke, not to omit the labours of Windhausen and Giffard, and finally the experiments and calculations of Sir W. Thomson (now Lord Kelvin), by whom Mr. Coleman was introduced to the Messrs. Bell, who were at that time importers of meat from the United States on the method mentioned by Mr. E. G. Constantine.

During six years experience with the Haslam-Bell-Coleman machine, the author had, personally, never known an accumulation of ice and snow in the expanders, sufficient to impair the working of the machine or force off the covers; but the discharge ports would close up to a certain extent, until the snow would be blown through by the discharging air.

The only advantage obtained by the discharge ports being on the bottom of the cylinder was, the air passed directly from the cylinder into a straight trunk without bends, as properly dried air would deposit but little snow, and the colder the discharge the less snow was formed.

Referring to the results given on page 106, these figures were from the log, corrected by the New South Wales Government Official, at the Official trial, and given by Mr. Coleman before the Glasgow Philosophical Society in January, 1883.

The author had obtained as low as $-98°$ F. from a 10,000 cubic feet machine at 50lbs. air pressure (Haslam compressor, diagonal, and Bell-Coleman expander, vertical), and during six hour's trial at full speed not more than $\frac{1}{4}$in. of snow was formed on the valves owing to the perfect dryness of the air.

In reference to the drying pipes, this part of the apparatus accomplished two purposes, viz :—drying the air, and cooling it. In the first place, no matter what water cooling surface employed, it was impossible to reduce the temperature below that of the water; by the use of the drying pipes, which were practically a part of the cooler, but with a different cooling agent, the compressed air was further subjected to a reduction of temperature by surface contact with the cold air returning from the chamber, which often registered 35° to 40° F, and should the circulating water be as high as 80° to 90° (not by any means uncommon in warm latitudes) the efficiency was increased 40 per cent, besides the fact that little snow was formed under such conditions when drying pipes were used.

The apparatus used by Messrs. Hall was an ingenious one, and accomplished the same work that would otherwise require a much larger cooling surface, and consequent increase of cost and space; the fact that moisture was abstracted and passed out by the float valve in the form of water proved its utility.

The proper form of lubricating air compressors was by an automatic apparatus, connected to any moving part of the rods, using Englebert's oil. The author found no difficulty with the Haslam compressor, and the oil would only burn on when lubrication was neglected, after which nothing but a thorough cleansing of the parts would free them from clogging.

Replying to Mr. Sayers, the freight per lb. from New Zealand and Australia was: beef 1d., mutton and lamb $\frac{1}{16}$d., butter $1\frac{3}{16}$d., cheese $\frac{1}{8}$d., and fruit 4s. per case containing an average of 50 lbs. Storage can be obtained in London at $\frac{1}{8}$d. per lb. per month; Liverpool $\frac{1}{8}$d. to $\frac{3}{16}$d. Freights were not fixed, prices fluctuating with the season and market, but these quotations applied to any of the principal ports of the United Kingdom.

In conclusion Mr. Quicke thanked the members for their attention and reception of the paper, and also took the opportunity to thank Mr. West for his kindness in encouraging and promoting the success of the subject.

On the motion of Mr. T. Ashbury (past-President), seconded by Mr. E. Marshall, a vote of thanks by acclamation was passed to Mr. Quicke, who briefly acknowledged the same, and the proceedings concluded.

DIAGRAMS.

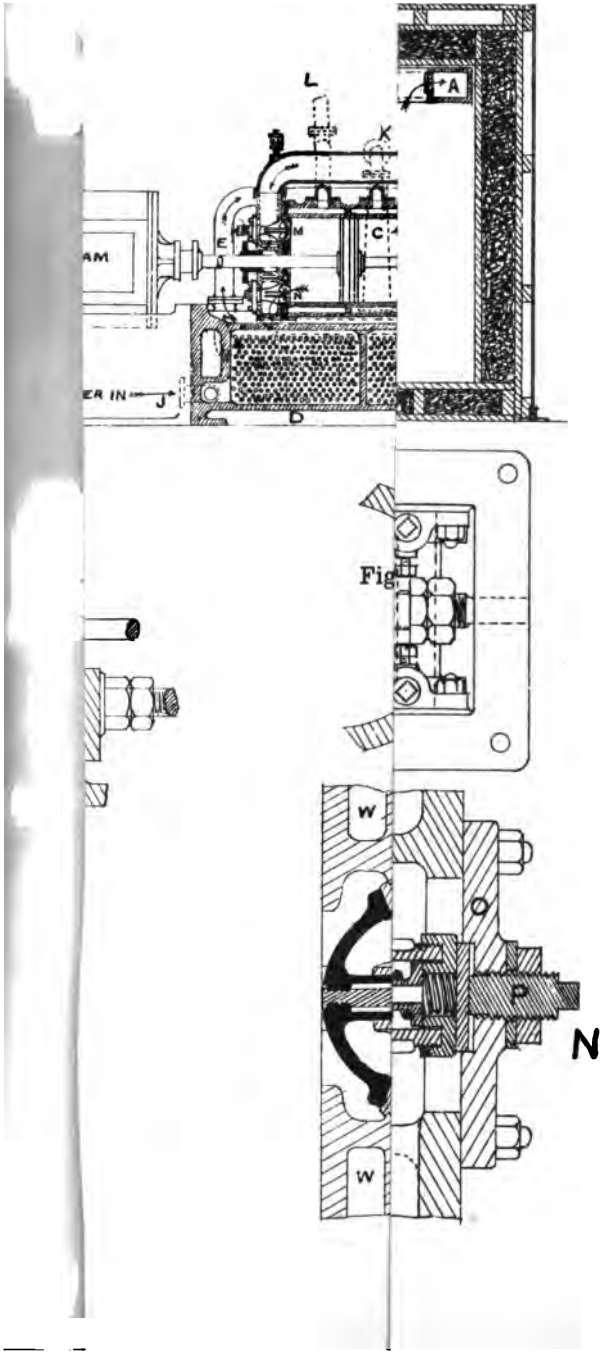
ING
SS ON
AN PAT

ING MACHINERY.

SS ON THE RETURN AIR

AN PATENT.

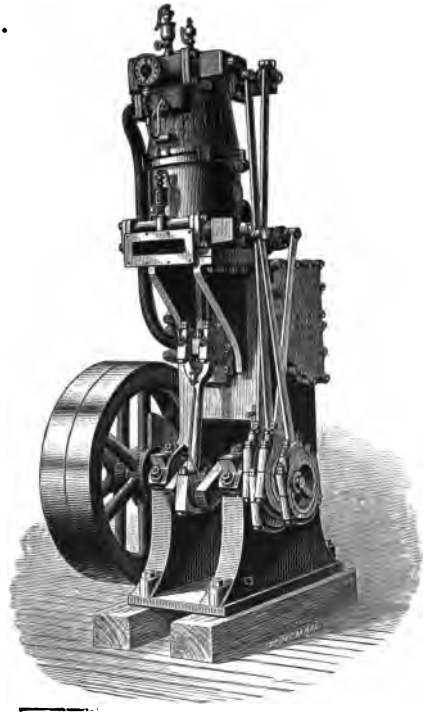
Plate I



UNIV. OF MICH.

UNIV. OF MICH.

Fig. 1.



BELT POWER MACHINE.

2,000 CUBIC FEET DELIVERY PER HOUR.

MANCHESTER ASSOCIATION OF ENGINEERS.

DRY AIR REFRI

LIGHTFOOT'S

Fi

COMPOUND SURFACE CONDE

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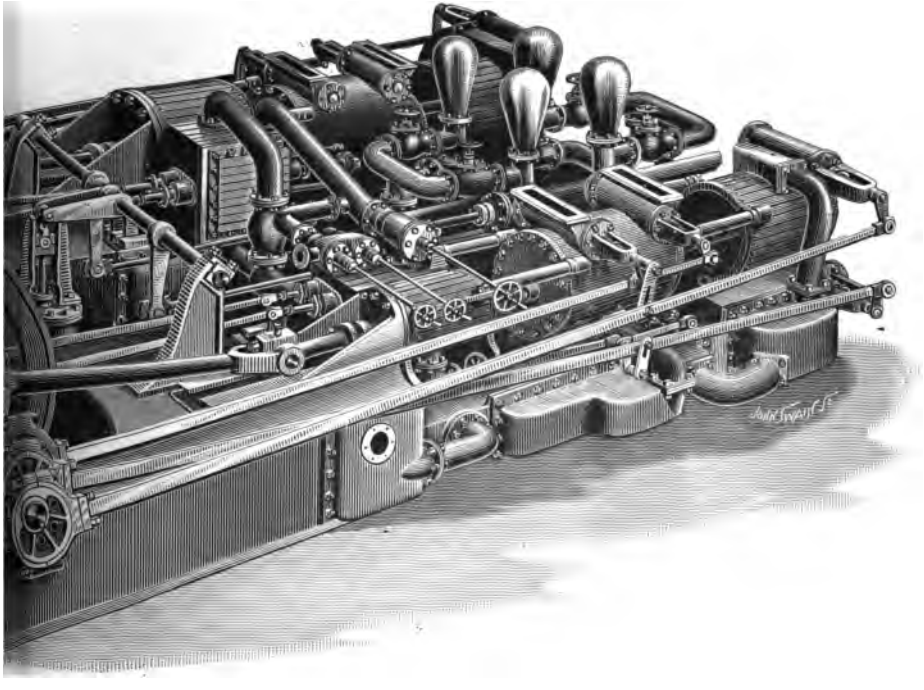
Plate 8.

IATING MACHINERY.

DRY AIR MACHINES.

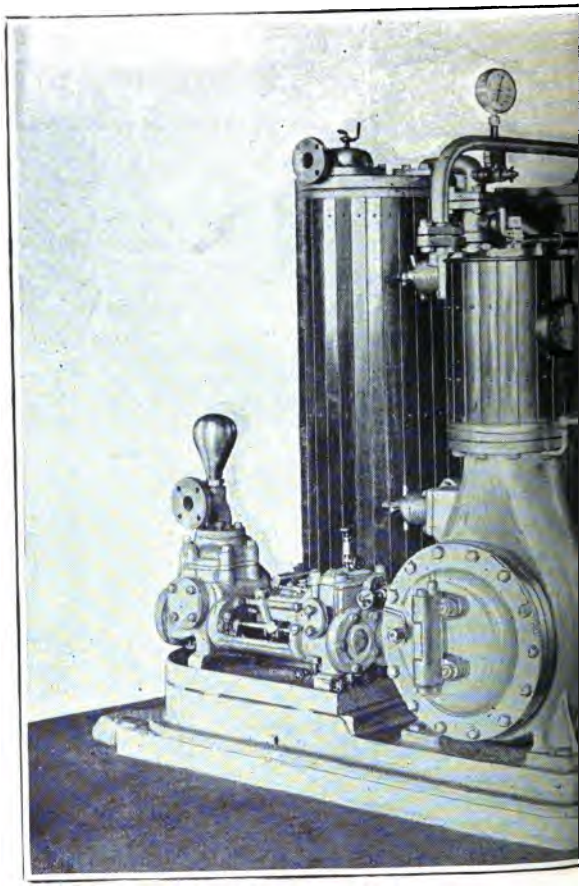


ING DUPLICATE COLD DRY AIR MACHINE, DELIVERING 180,000 CUBIC FEET PER HOUR.

"ELGINSHIRE," FOR THE NEW ZEALAND TRADE. CAPACITY 60,000 CARCASES.

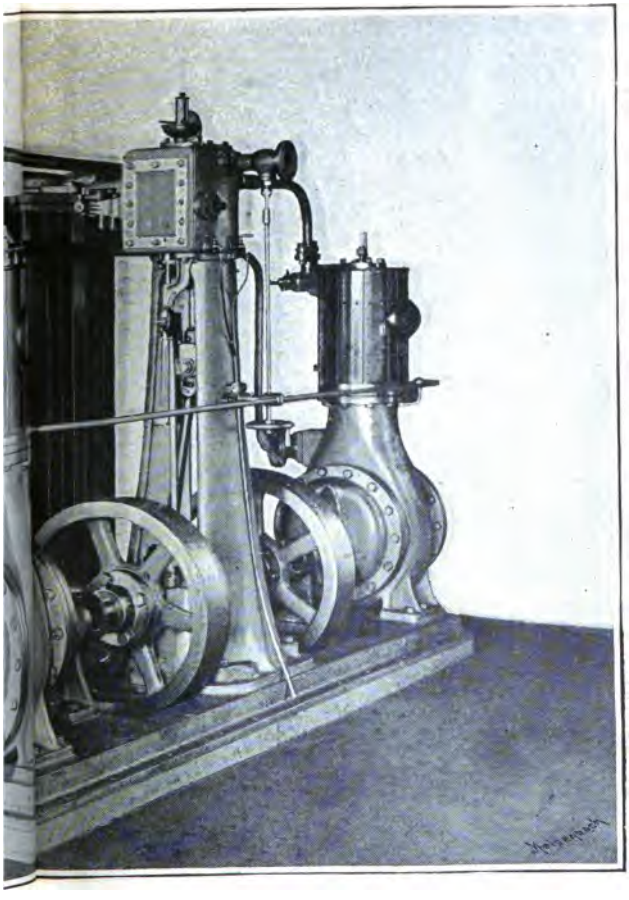
UNIV. OF MICH.

DRY AIR REFRIGEI



THE KILBOURN AMMONIA M

MANCHESTER ASSOCIATION OF ENGINEERS.



ONIA MACHINE. MARINE TYPE.

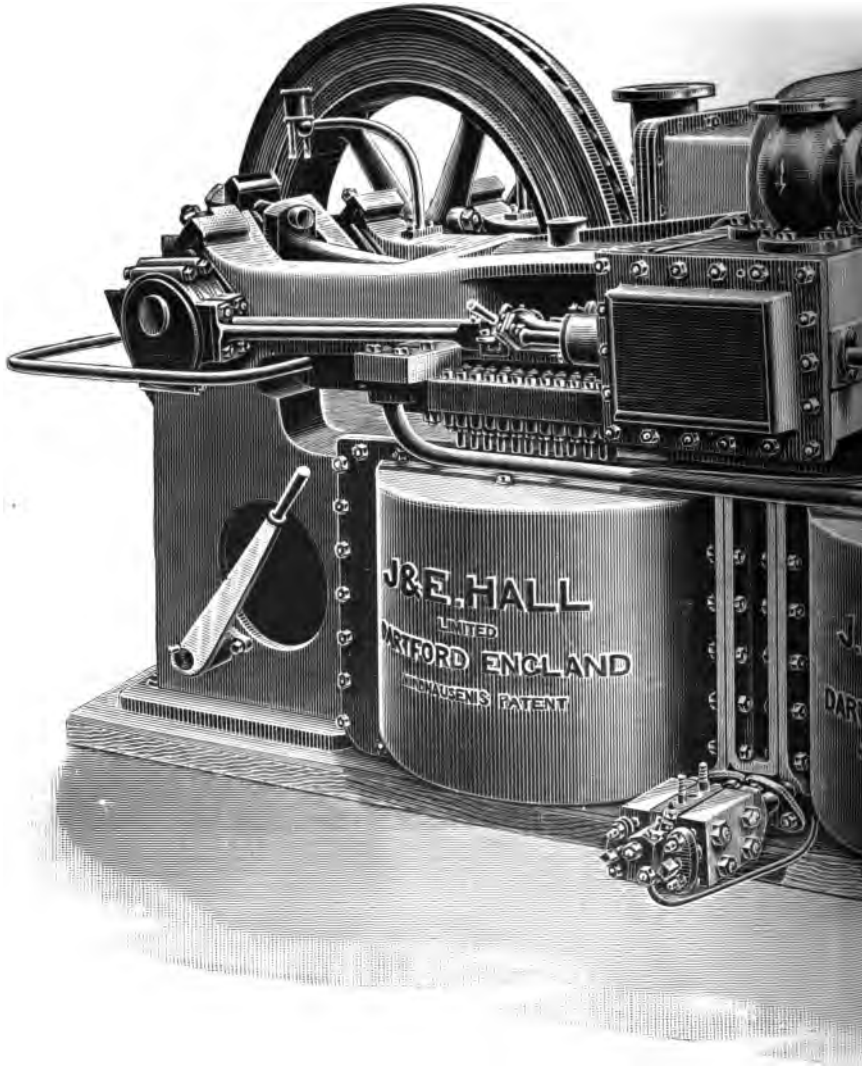
UNIV. OF MICH.

DRY AIR REFRI

HALL'S PATENT C

S.S. "I

RIVER PLATE S. A. TRADE.



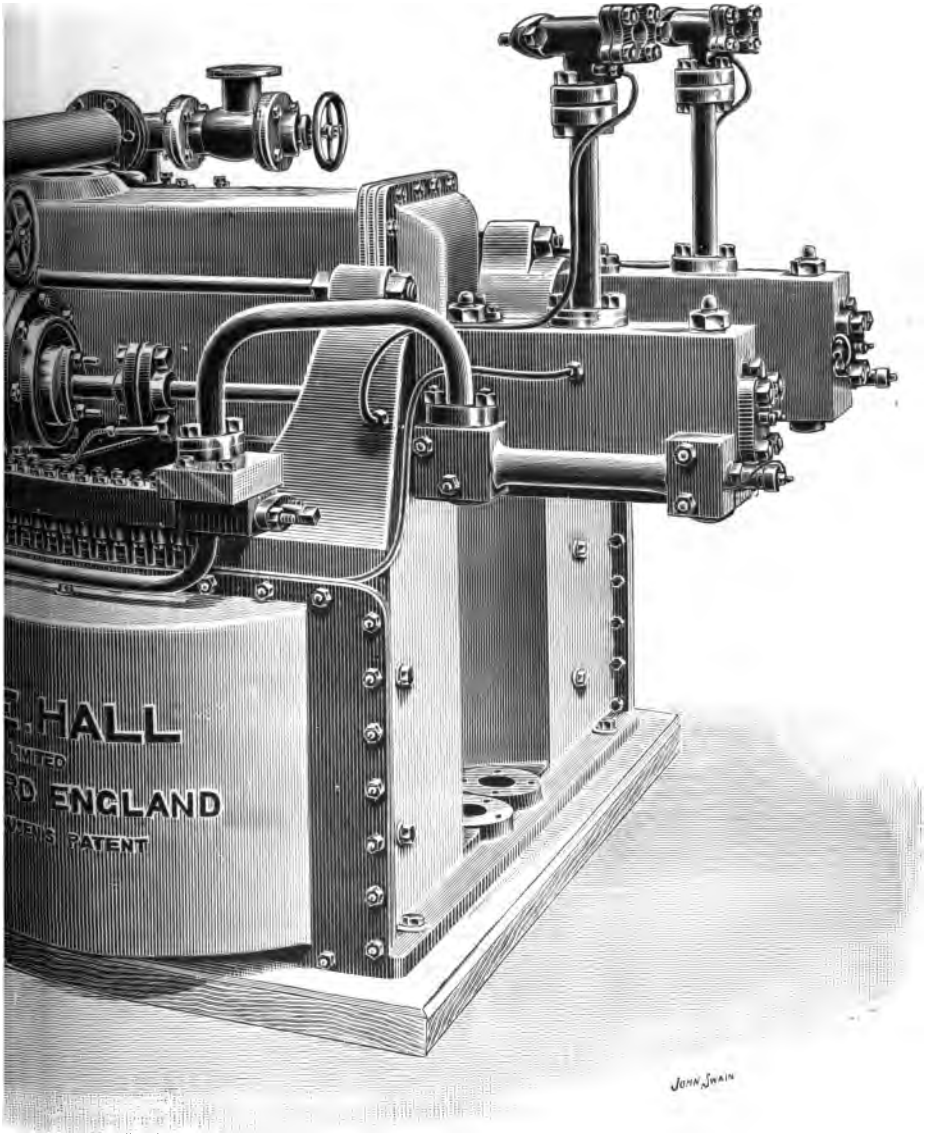
COMPOUND DUPLEX MACHINE. I.H.P 65.

RATING MACHINERY.

NIC ANHYDRIDE MACHINE.

LAND MARY."

ACITY 50,000 CARCASES OF MUTTON.



SPACE OCCUPIED 15FT. 0IN. LONG, 8FT. 6IN. WIDE X 6FT. 4IN. HIGH.

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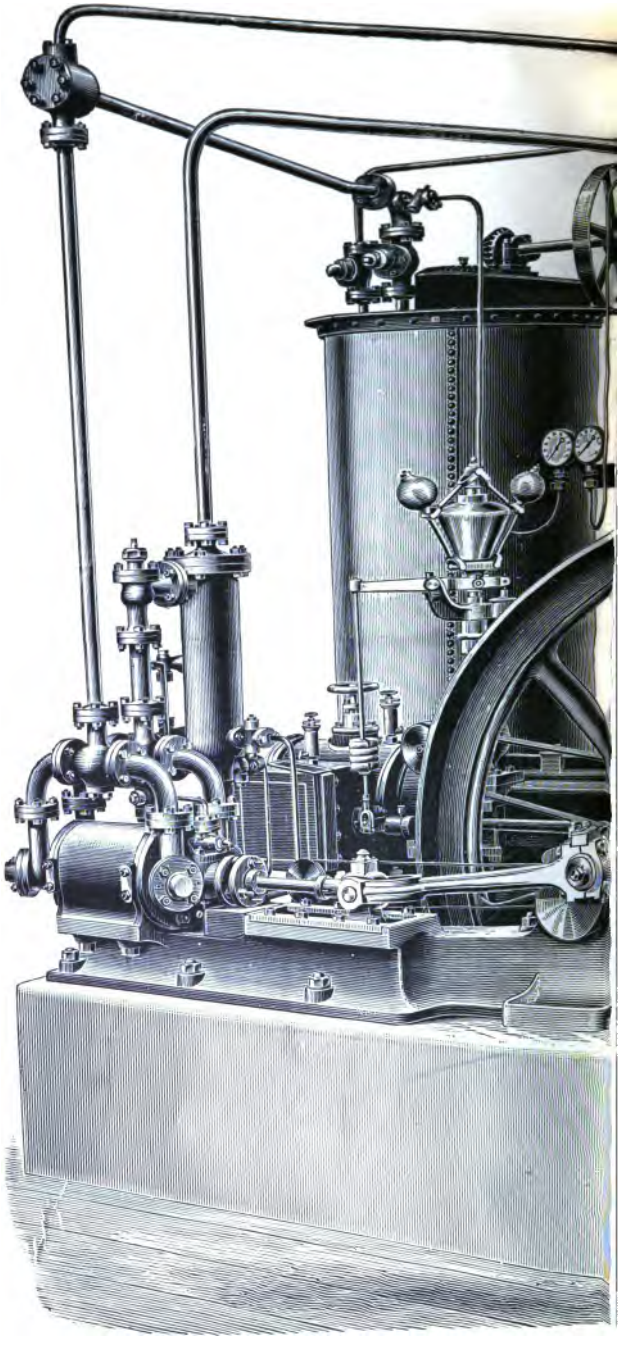
UNIV. OF MICH.



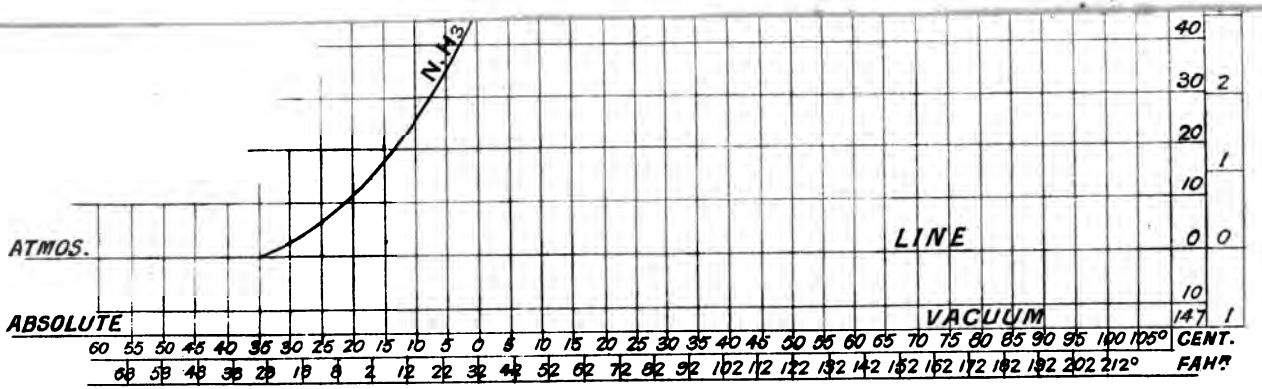
THE "LINDE" AMMONIA COMPRESSIO

MANCHESTER ASSOCIATION OF ENGINEERS.

PRESSION MACHINE. LAND TYPE.

UNIV. OF MICH.

DRY AIR REFRIGERATING MACHINERY.



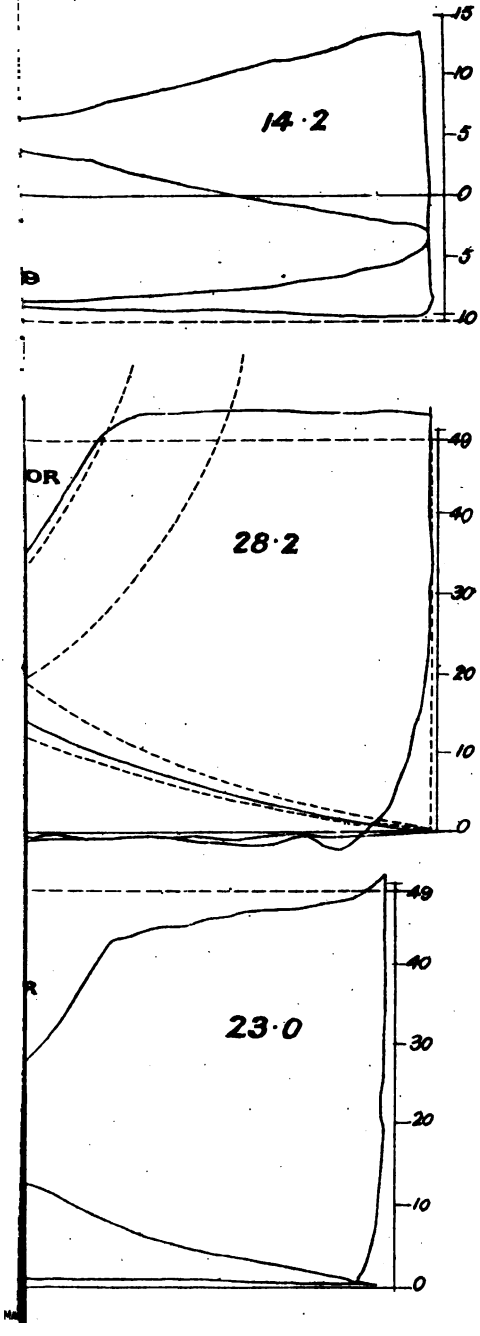
UNIV. OF MICH.

MACHINE.

·OINT COMMITTEE.

IA DOCK.

105,000 CARGOES



Stroke 3ft 0

BORE OF CYLINDERS.

H.P. Steam ... . 20in.

L.P. „ ... ... 31·25in.

Air Compressors 25·25in.

Air Expanders 19·5in.

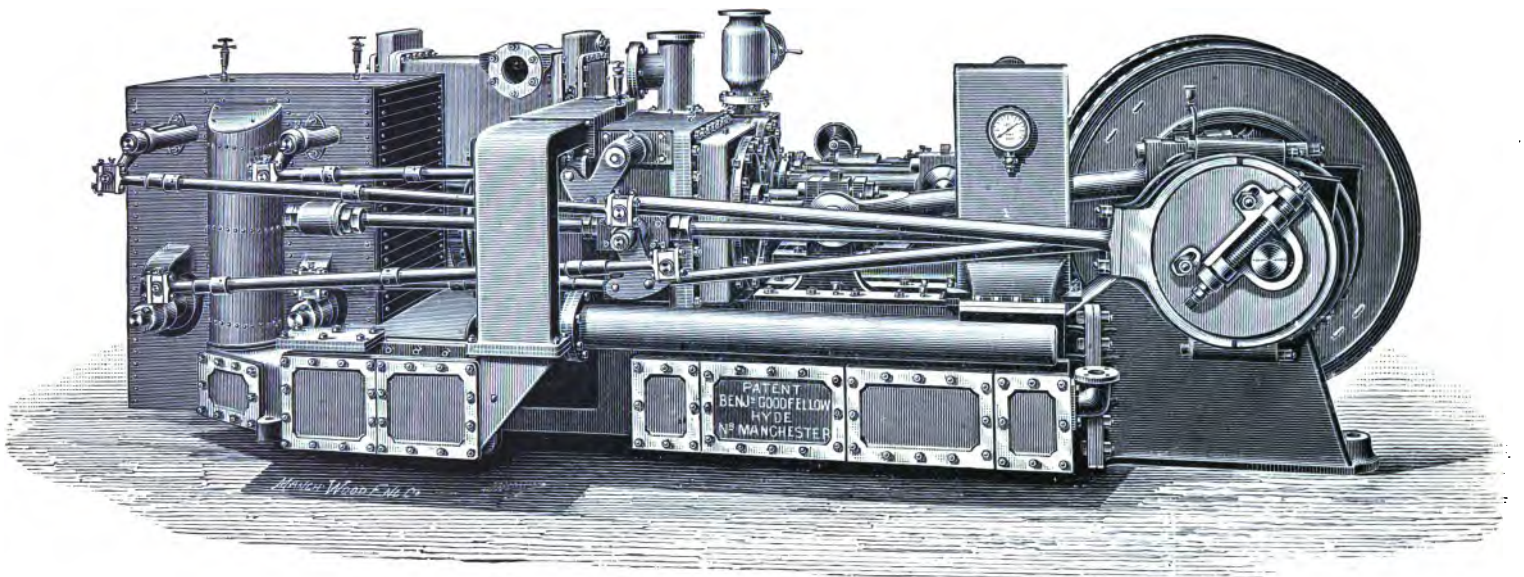
Steam pres.	Steam Cut-off	Revolutions	Vacuum	Air Pressure	Air Cut-off	Circulating Water	Air discharge in Snow-box
91 lbs on gauge	H.P 18in. L.P 27in.	72	26in	49lbs. on gauge	13·5in.	40°	- 85°

UNIV. OF MICH.

Dry Air Refrigerating Machinery.

Plate 15.

Goodfellow's Cold Dry Air Machine.



70,000 Cubic Feet Delivery Per Hour. Land or Marine Type.

UNIV OF MICH

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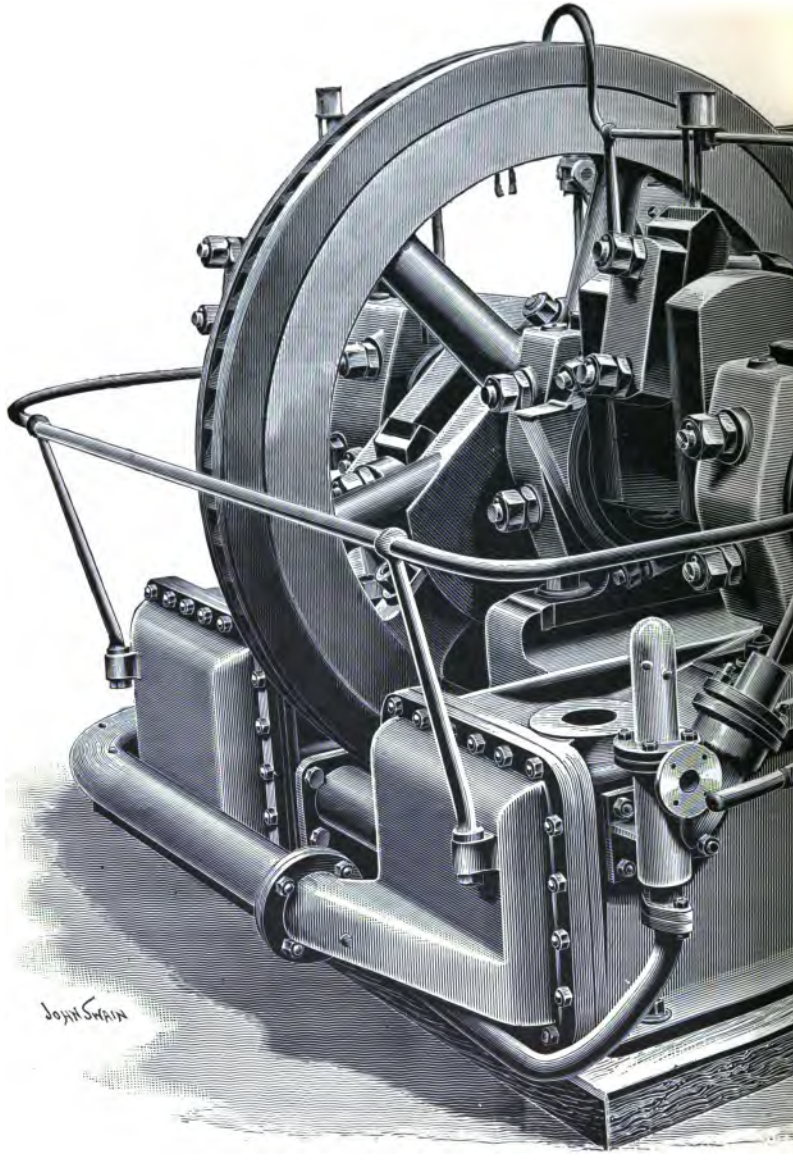
DRY AIR REFRIGE

HALL'S PATENT SURFACE



70,000 CUBIC FEET DELIVERY PER HOUR. SPACE

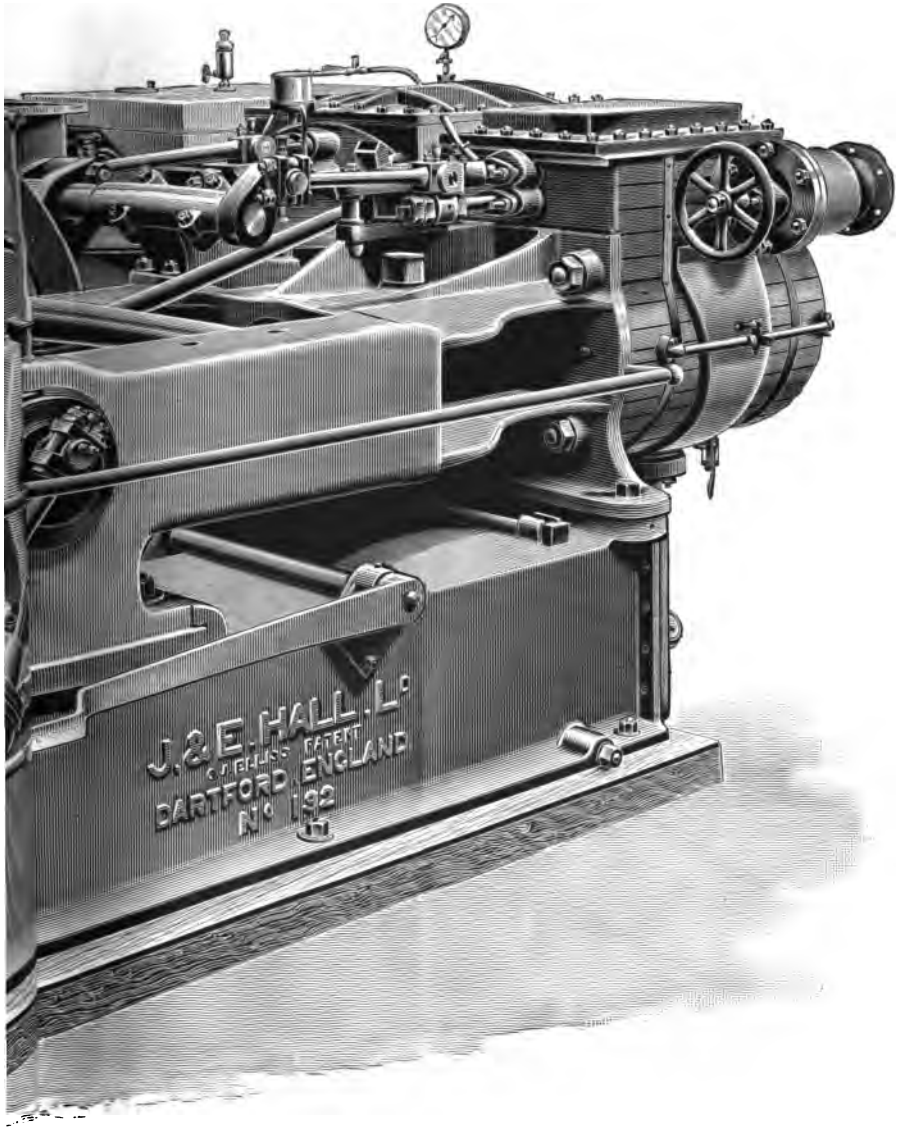
NEW ZEALAND

MANCHESTER ASSOCIATION OF ENGINEERS.

RATING MACHINERY.

Plate 16.

COOLING COLD AIR MACHINE.



SPACE OCCUPIED: 14 FT. LONG x 8 FT. 10 IN. WIDE x 6 FT. 4 IN. HIGH.

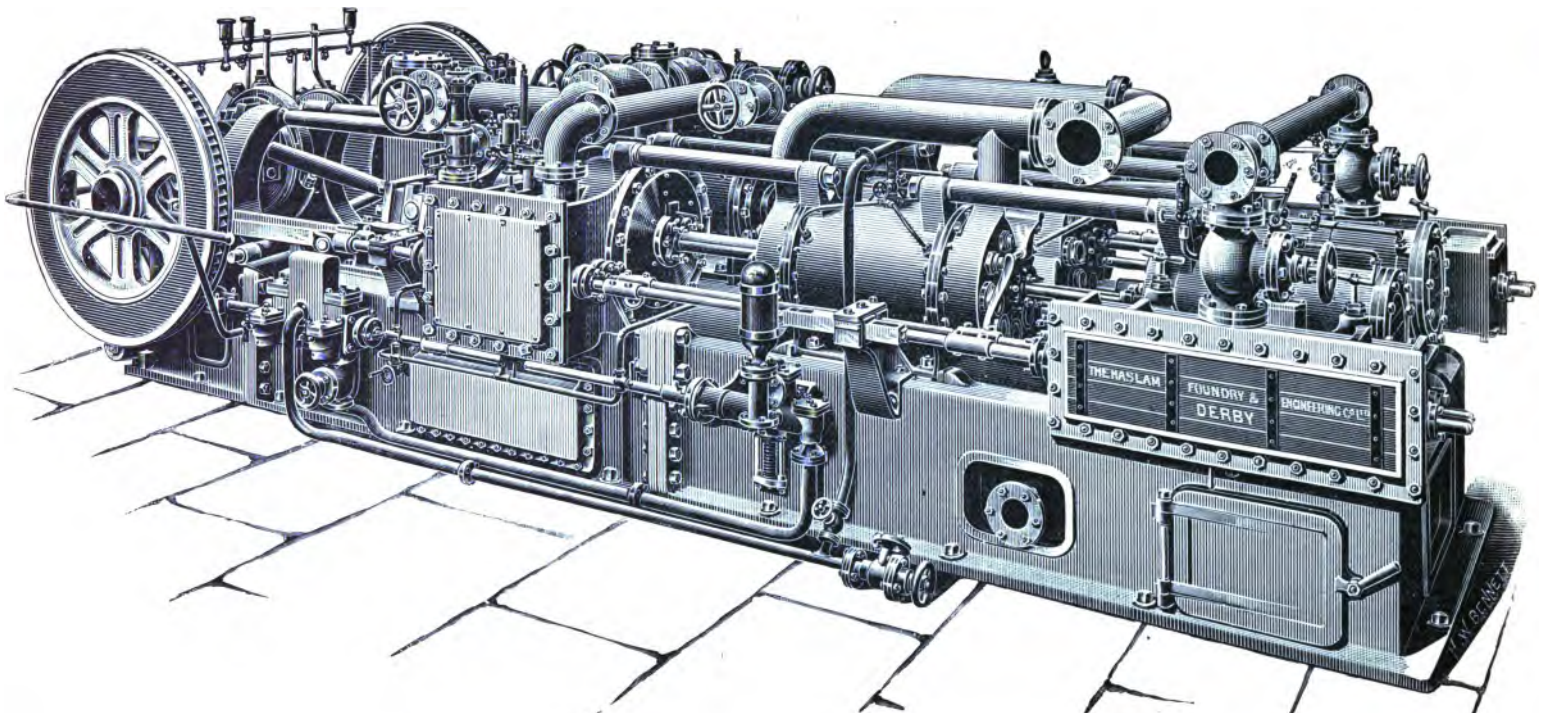
AND A RIVER PLATE TRADE.

UNIV. OF MICH.

Dry Air Refrigerating Machinery.

Plate 17.

Haslam Foundry & Engineering Company, Derby.



Compound Duplex. 300,000 Cubic Feet Cold Air Machine, on Bell-Coleman System. Injection Principle.

UNIV.
OF
MICH.

PAPER-MAKING PROCESSES AND MACHINERY,

BY

Mr. J. B. BENNETT, Assoc.M.Inst.C.E.,

OF EDINBURGH.

(Communicated by Mr. A. REA, of Manchester, to the Manchester Association of Engineers.)

SATURDAY, 9TH APRIL, 1892.

ANTIQUITY OF PAPER MAKING.

The art of making writing material from vegetable fibres has been practised from very ancient times, although it is not of such great antiquity as weaving or the manipulation of the more ductile metals, but curiously enough, some of the ancient civilised nations, such as those resident in Mesopotamia, appear to have been ignorant of it. The earlier processes were, no doubt, of a purely mechanical character, consisting chiefly in the beating out to a uniform surface the compact tissues of the bast or inner bark of trees and plants. A process of this nature is still in use in Japan, where one form of the soft Japanese paper, with which we are now so familiar, is prepared by the most primitive means from the bast of a species of mulberry, which is simply cut into pieces and hammered out to produce a surface of the requisite evenness.

Of more complex processes, the earliest of which we have any record is that of the manufacture of papyrus from the paper reed as practised in Egypt. Egyptian papyri dating back to 2000 years B.C. have been preserved.

The use of papyrus was very widely spread in the ancient world. It is known to have been used in Greece 400 B.C., and in Rome itself, under the Empire, a manufacture of some kind connected with papyrus was carried on, though it is probable that this was the production of larger and stronger sheets by the union of the smaller sized sheets of different qualities rather

than the manufacture of the material itself, which would appear to have been exclusively confined to Egypt.

MANUFACTURE OF PAPYRUS.

Pliny, in his Natural History, has preserved for us an account of the manufacture of papyrus, from which it would appear that the stem of the reed was first cut into longitudinal strips by a sharp knife, those from the centre of the plant being the broadest and most valuable. These strips were laid on a board side by side to the required width, thus forming a layer, above which another layer of shorter strips was laid at right angles. These two layers thus woven formed a sheet which was soaked in water. It is not quite clear from Pliny's description whether some peculiar property of the Nile water acted as a solvent upon some glutinous matter contained in the material itself which caused the layers to adhere, or whether a paste was actually used, but be this as it may, the sheet thus formed was finally pressed and dried in the sun, any roughness being removed by polishing with ivory or a smooth shell. The papyrus sheets thus produced were very small, being barely 10ins. in breadth, but sometimes the finer sheets were joined together with a backing of a coarser quality, producing sheets up to 18ins. wide, and these sheets were again joined together by pasting the edges to form rolls. Papyrus continued in use in many parts of Europe for a long period, and even in the tenth century it was used exclusively for Papal Bulls, but after the twelfth century its use almost wholly ceased, vellum and pulped paper being used instead.

PAPER MAKING FROM FIBROUS SUBSTANCES.

The art of making paper from fibrous substances reduced to a pulp appears to have been first known to the Chinese, who certainly practised it in the first century A.D., employing, among other materials, the wool of the cotton plant. It was not, however, until the eighth century that pulped paper became known to the western world, its introduction being due, like a great many other useful arts, to the Arabs, who probably acquired it from the Chinese at the capture of Samarcand in A.D. 704. At all events, the manufacture was taken up by them in that city and gradually spread through all parts of their

empire. Large quantities of it were produced for a long time in Damascus, and imported through Greece into Europe, where, during the middle ages, one of the names for paper was *Charta Damascena*.

The manufacture of cotton paper in Europe was, as was natural, first established in those countries which were most in contact with Oriental influences, as in Spain by the Moors, and in Italy through the Arab occupation of Sicily. As the industry spread further north to districts where cotton was not to be found as a natural product and was not imported, other substances had to be pressed into the service. Hence arose the use of rags, first woollen, then linen, which extended until linen and flax fibres formed the staple material. The earliest notice we have of rag paper is a reference in a work of the twelfth century, in which woollen rags are probably meant. Linen paper was first made in the fourteenth century, when paper-making had become an established industry in northern Europe, and about the same period, according to some authorities, water-marks were first introduced, the Oriental papers not having had any. Mills were started in Germany in the fourteenth century, and in Holland a little later, and by the middle of the fifteenth century the use of paper for all literary purposes had gradually superseded vellum.

PAPER MAKING IN BRITAIN.

Paper was in very general use in Britain at the beginning of the fourteenth century, but there is no evidence that it was manufactured in this country before the beginning of the sixteenth century; one, Tate, who set up a mill at Hertford about that time, being the first known paper-maker in England.

Paper-making does not appear to have been introduced into Scotland till 1675, when a mill was set up near Edinburgh, on the water of Leith, but there is reason to conclude that this mill was not continued, and the manufacture of paper in Scotland was not successfully begun until the middle of the eighteenth century.

MATERIALS REQUIRED FOR MAKING PAPER.

Down to 30 years ago, rags—cotton and linen—and mill wastes formed the staple material of paper-making; but the largely

increasing demand for paper has led manufacturers to look to other sources for the bulk of their raw materials. It has been said that the paper industry subsists upon the rejecta of the textile manufactures, but as paper-making requires that the raw materials shall be reduced to the condition of minute sub-division of the constituent fibres, it can, in addition, avail itself of materials which are valueless to the spinner, and paper is now made from a great variety of fibres. Chief among these in Great Britain are esparto and wood pulp, which may now, rather than rags, be considered the staple paper-making materials.

ESPARTO PULP.

Esparto grass, the leaves and shoots of which are the parts used, is a native of the south of Spain and the north of Africa, and grows in patches to a height of from one to three feet. It has been in use for centuries for ropes, baskets, matting, &c., on account of the strength of its fibre combined with its lightness, hawsers made of it being so light as to float on water. For paper-making esparto was first utilised by the French, but in 1856 it was first used in England, and in that year ten tons of it were imported. In 1857, Mr. Routledge, of the Eynsham Paper Mills, near Oxford, began to use esparto systematically on a small scale, and the process gradually developed.

In 1861 the Board of Trade first separated esparto from other paper-making materials in their return of imports, and set down 891 tons as the quantity brought into the country. Its use was favoured by the outbreak of the American Civil War, and the consequent scarcity of cotton, and the imports of esparto rose to 20,062 tons in 1863, and 55,726 tons in 1867. They have gone on steadily increasing since, and at the present time upwards of 180,000 tons, of a value of over £1,000,000 sterling, are annually imported into this country.

WOOD PULP.

Wood-pulp, imported into Britain chiefly from Norway and Germany, has been largely used of late years in the manufacture of the cheaper papers. This pulp is prepared either chemically, or mechanically by grinding, and the chemical processes, of which there are several, produce a pulp of excellent quality. Mechanical wood-pulp has the advantage of being cheap, but

paper containing it is very liable to become discoloured by the action of air and light, and the fibre is, moreover, devoid of much felting power, and has little in fact to recommend it but its comparative cheapness. It is, nevertheless, used in large quantities, some cheap papers being made entirely from it.

The manufacture of wood pulp from white pine timber has increased in Norway from about 20,000 tons in 1880 to 150,000 tons in 1887, and during the last five years there has been a great augmentation. It is said on good authority that more than two-thirds of all the wood-pulp made in Scandinavia is imported into Great Britain. Wood-pulp is largely used in America, but there poplar wood chiefly forms the raw material, and it is claimed that it gives better results than pine.

STRAW PULP.

Straw has been used for paper-making for many years, and a book was printed in London in 1801 on paper made wholly from straw, but in general this material is mixed either with rags or esparto, as it produces a very brittle paper when used alone. Many other fibres are employed in paper-making, among which may be mentioned jute and hemp—chiefly in the form of sacking and old ropes—for brown paper, peat, bamboo, sugar-cane refuse, China grass, sunn, pine-apple, New Zealand flax, yucca, aloe, and the common nettle, which possesses a strong fibre somewhat akin to flax, but the use of some of these is chiefly by way of experiment and calls for merely passing notice.

INDIAN GRASSES.

Of recent years several paper mills have been established in India, chiefly for the manufacture of the commoner papers from jute. Some of these mills are large and successful, paying dividends from 10 per cent. to 16 per cent. per annum over a course of years. Some of the Indian newspapers ask: Why should not India ere long supply paper to Europe as it now supplies manufactured jute? But owing to the cost of chemicals, coals and transport, it is not likely that paper could be exported to Europe at a price to compete with home manufactures.

Experiments have also been made in the use of rhea grass with the object of establishing mills in Australasia, but they have not as yet been very successful.

PROCESSES NECESSARY FOR PAPER PRODUCTION.

While the processes necessary for the production of paper vary much in detail according to the nature of the materials employed and the class of paper intended to be produced, they are all based upon the same general principles, and they may be divided into three main groups: First, the complete separation of the fibrous parts of the raw material from the cellular portions which, combined with them, go to make up the entire plant; second, the reduction of these fibres to the condition of a fine pulp; and third, the transformation of this pulp into paper.

It is evident that those materials, such as bleached cotton and linen thread and rags, which have already undergone treatment by the textile manufacturer and in which the fibres are therefore more or less completely isolated, require but little chemical treatment at the hands of the paper-maker, whose attention is therefore chiefly directed to the removal of such substances as size, grease, etc. In other raw materials, such as esparto, straw and wood, there are in addition to the fibrous compounds which form so to speak the groundwork of the material, a certain proportion of silica, also gummy and resinous matters, the removal of which has to be brought about.

PICKING AND SORTING.

The first stage in the process of manufacture is that of picking and sorting the raw materials. In the case of rags, which vary greatly in quality, from clean, almost unused, portions to the very foulest descriptions, the first thing to be done is to sort and cut them into pieces of a convenient size.

The cutting may be done either by machine or by hand, but the latter is preferred by many manufacturers, especially for the finer classes of paper, as by it more perfect removal of impurities can be effected. This work is almost invariably performed by women, who stand at tables into which broad knives are fixed. Each worker is provided with a number of boxes, into which the different qualities of rags are put. The sorting is done on purely arbitrary lines, the colour and the material of which the rags are composed being the guiding features, and all foreign substances, such as buttons and hooks, are carefully removed.

A rag cutting machine is very simple; the material is passed along a table at the end of which is a fixed knife, beside which is a revolving drum carrying three or more knives on its rim, and as the rags are pushed forward they are caught between the knives and cut up. A similar machine is also used for chopping up ropes.

For the removal of dust and all loose extraneous matter, the rags are generally passed through a machine known as a combined willow and duster. In the willow there are two revolving drums with teeth by which the rags are beaten, after which they are passed into the duster, which slopes, so that, as it revolves the rags travel along and are discharged at its lower end, and the frame being also fitted with teeth, the dust is pretty well driven out by the time the rags are discharged from it.

Raw fibres, such as esparto and straw, are passed through a similar machine and are also subjected to a preliminary picking process, all root ends and weeds and other foreign substances being carefully removed. This is known as dry picking, to distinguish it from a subsequent picking which the materia sometimes undergoes after it has been boiled.

BOILING.

Rags, straw, ropes and waste for the commoner classes of papers, are generally boiled in spherical boilers which are made to rotate and thus circulate the liquor, the lye and steam being admitted through hollow journals.

The class of boiler used for esparto is an upright fixed boiler constructed upon what is known as the vomiting principle. In this boiler the steam is admitted from the top by a pipe, which passes right down the centre inside a larger tube and through the false bottom of the boiler, and by its action the lye which has percolated through the grass in the boiler to the space below the false bottom is forced up the wide pipe, and striking against the dome at the top is distributed over the surface of the grass. In this way a constant circulation of the lye is kept up.

Several patent boilers on this vomiting principle have been introduced. Of these Sinclair's is perhaps as well known as any. It has two vomiting pipes made of thin steel plates and rivetted to the sides of the boiler. The liquor when forced up

the vomiting pipes is distributed through perforated plates over the grass in a number of fine jets. In Roeckner's patent boiler, another modification, the vomiting pipe is outside the boiler.

The alkali employed in boiling, which is necessary for the removal of the resinous matters contained in the raw material, may be in the case of rags, caustic lime, caustic soda or carbonate of soda, but in the case of esparto and of straw, caustic soda is alone used, as lime forms insoluble compounds with the non-cellulose portions of the grasses. The proportion of caustic soda used is about 10 per cent. of the dry weight of the raw material, and this is first dissolved in water and introduced as a lye into the boilers. The steam is used for the purpose of raising the temperature, the necessary circulation of the liquor being produced in the manner already described. It is found that it is possible by increasing the pressure of the steam to do with a smaller proportion of caustic acid, or *vice versa*, and to such an extent can this be carried on, especially with esparto, that in some mills this material is boiled in open vessels with, of course, a very strong lye.

The pressure of steam in esparto boilers varies from 10 to 45lbs. per square inch, and there is a growing tendency to adopt higher pressures, even up to 70lbs., on account of the economy of soda effected, although a little fibre is lost. The time occupied in boiling varies from two to ten hours according to the material, the chemicals used, and the pressures.

When the boiling is completed the pressure of steam is allowed to fall, and the waste liquor drained off; the contents of the boiler then receive a preliminary washing with clean hot water. The quantity of water should be kept as small as may be, more especially in cases where it is necessary to evaporate the whole of the waste liquors, and it is the practice in some mills, *e.g.*, in in some of those on the River North Esk, in Midlothian, to wash the grass in a series of tanks connected together in the same way as the lixiviating tanks of an alkali works. They are so arranged that pure water flows in at one end, passes through fresh lots of grass in succession, and issues at the further end highly charged with the soluble products of the grass, and this final washing is sometimes used to dissolve the soda for the lye. By such an arrangement the grass can be

washed without any loss of fibre, and with a minimum quantity of water.

After the washing, the fibres are removed into convenient receptacles, generally iron boxes on wheels, and are taken to the breaking engines.

(Note.—The process of Soda Recovery is alluded to at the end of this paper.)

WASHING AND BREAKING.

The boiling process has removed all cell substances and fibres only remain. These have now to be pulped, and they are, first of all, placed in what is termed the washing engine or breaker. This engine is an oblong vessel of cast iron, with rounded ends, and is made in many sizes, from about twelve feet long by six feet broad and two feet deep, upwards. The smaller sizes are usually cast in one piece, but within recent years it has been made in sections of cast iron plates securely fitted together to any desired size. Messrs. Bertrams Limited, of Edinburgh, have made these engines up to over 24ft. long, and the working results have been remarkably successful.

In the centre is a partition or "Midfeather" which, however, does not reach to either end. In one of the compartments is placed a roll about three feet in diameter, or larger according to the size of the engine, which is provided with knives arranged parallel to the axis in groups all round it. In the bottom of the vessel immediately underneath the roll a bed-plate provided with similar knives is placed, but they do not lie parallel with those of the roll, and in this way the action of a pair of scissors is imitated to some extent.

The roll is made to revolve rapidly, and by its action the fibres are made to pass between it and the bed-plate, where they are caught and broken up by the knives. It will be easily seen that the action of the roll causes the pulp to travel constantly round and round the vessel, and advantage is taken of this to wash thoroughly away all traces of the lye with which it was boiled. The dirty water is removed by means of a revolving drum washer covered with fine wire cloth, containing scoop-shaped blades inside which lift the water and throw it upon the hollow axle of the drum, through which it runs to waste, its place being supplied by a constant flow of clean water into the breaker.

BLEACHING.

When the pulp is thoroughly washed, it is bleached, and this is usually done in the breaking engines, though frequently the operation is performed in special engines resembling breakers, termed potchers.

The bleaching medium usually employed is a solution of chloride of lime (bleaching powder) in water, prepared in a vessel provided with stirrers or agitators whereby a thorough mixture of the bleaching powder and water is obtained.

The amount of bleaching powder necessary varies very much with the fibre, but in well-boiled pulps it may be taken that esparto requires 10 per cent. to 15 per cent. of its weight before boiling, straw 7 per cent. to 10 per cent., and wood 15 per cent. to 20 per cent. This method of bleaching by solution of chloride of lime is the one in general use, but others, such as the use of chlorine gas and of acetic acid, have been adopted.

Various attempts have been made from time to time to bleach textile fabrics and paper pulp by means of electricity, or to speak more correctly, by means of solutions which, containing alkaline chlorides in such small quantities as to be practically useless for bleaching purposes, have their contained chlorine so acted upon by the decomposing action of an electric current as to render them efficient bleachers. Inventors have proved that pulp can be bleached by such processes, but up till now have failed to convince manufacturers of their utility and economy.

PREPARATION OF WOOD PULP.

The process of preparing wood pulp, which is only carried on in this country to a very limited extent, ought here to be referred to. Mechanical wood-pulp is obtained by disintegrating wood by mechanical means alone, no chemical being employed. The wood is first cut into blocks and any knots present are cut out. The stones by which the blocks are ground down are made of a hard sandstone, of which only one quadrant is exposed for use, the remaining three being covered by an iron casing. The surfaces of the stones are kept rough by the pressure of steel rolls studded with points which are pressed against them while revolving, and in addition channels about ¼inch deep are cut into the stone at distances of two to three inches. These serve to carry off the pulp to the sides of the stones, in addition to

giving increased grinding power. The pressure of the blocks of wood against the stones is steadily maintained by screws worked by suitable gearing. This is necessary in order to obtain a pulp of uniform character. A stream of water is kept constantly playing on the stone, and by this means the pulp is carried away as fast as it can be formed.

Chemical wood-pulp is somewhat difficult of preparation, it being necessary to boil the wood at temperatures corresponding to pressures of six to ten atmospheres; and as the use of strong caustic soda solutions at high temperatures is attended with very serious objections, apart from the question of cost, various processes have been from time to time proposed in which the hydrolytic agent is a solution of sulphurous acid in water, either alone or in combination with a base. These latter are the processes generally used, but their details need not be entered into here.

THE PRESSE PÂTE PROCESS FOR HALF STUFF.

The broken and bleached pulp, termed half stuff, is not yet sufficiently disintegrated for paper-making. If this were attempted the paper produced would be found wanting in evenness of texture and uniformity of surface, and the pulp has therefore to be subjected to still further treatment. It has become customary during late years, especially in the case of papers in which esparto or straw is the staple material, to treat the half stuff by what is termed the "Presse Pâte" process. This is in effect the conversion of the half stuff into a web on what is practically the wet end of a paper machine (afterwards described) and it has the advantage that the straining the pulp receives secures the complete removal of all hard unboiled portions of the fibres, and enables manufacturers to dispense to a great extent with the costly processes of dry and wet hand-picking. It also permits of the more thorough removal of the products of the action of the bleaching powder.

BEATING.

The pulp from the presse pâte machine, or the half stuff from the breakers, is now removed to the beaters. These resemble very much the breakers already described, the chief difference being that the roll carries a larger number of knives and that

it is brought into close contact with the bed-plate, by which means the half stuff is converted into fine fibrous pulp ready for the paper-making machine. The pulp remains in the beaters subjected to the action of the knives for a period of from four to six hours, and too much care cannot be given to this operation.

The length of the fibre to which the pulp should be reduced depends to some extent upon the kind of paper to which it is to be applied.

Messrs. Cross & Bevan state that they found the dimensions in millimetres of various pulps to be as follows :—

Fibre.	Maximum.	Minimum.	Mean.
Cotton	1·32 ...	0·23 ...	0·75
Linen	1·20 ...	0·20 ...	0·76
Esparto	1·40 ...	0·40 ...	1·00
Straw	1·50 ...	0·50 ...	0·88
Wood	2·60 ...	1·00 ...	2·00

(1 millimetre = practically $\frac{1}{25}$ inch.)

It is usual, except in the case of papers of the very highest quality, to add to the pulp a quantity of some cheap loading material, such as China clay, or pearl hardening, that is sulphate of lime. The addition of clay in moderate quantities serves to fill up the pores of the paper and enables it to take a good surface, and also enables the manufacturer to meet the demand for cheap paper, but when it is added to the extent of 20 °/₀ to 25 °/₀ it cannot be to the advantage of the consumer, and must be regarded as an adulteration.

FILLING UP INTERSTICES FOR WRITING OR PRINTING PAPERS.

Papers that are intended to be written upon with ink, and also most printing papers, require to have the interstices of the fibres filled up with some material which will to a greater or lesser extent resist the action of water, and thus prevent the ink or other liquid applied to them from running. This may be accomplished in two ways, either by adding to the pulp in the beater a mixture of resin with soda and starch, in which case the paper is termed engine sized; or after the paper is made it may be passed through a vessel containing a solution of gelatine, and afterwards dried by passing over a large number of light sparred rollers, and in this case it is termed tubsized.

Blotting paper and filter papers, which are unsized papers, are made with the addition of starch only, which binds the fibres together to some extent, while not preventing the paper from being absorbent.

COLOURING.

The fibres used for paper-making, except in very rare instances, are never sufficiently white of themselves to produce a perfectly white paper, and it is necessary to complement the slightly yellow colour which most pulps possess after bleaching by the addition of small quantities of blue and pink colouring matters, ultra-marine and smalts being the best blues, and cochineal the best red for this purpose, though aniline dyes are sometimes used. Papers of any desired colour or mottled colours may be made either by using rags previously dyed, or by adding to the bleached pulp in the beaters such colours as will obtain it, and any colour which can be obtained in the form of a fine powder or of a solution will suffice. The pulp having been beaten to the required fineness, loaded, coloured, and if necessary sized, is now run from the beaters to the stuff chests ready to be made into paper.

MODES OF MANUFACTURING PAPER.

So recently as the end of last century all paper was made in single sheets by hand, the paper-machine being, comparatively speaking, of recent invention, and still the best qualities of paper, especially of drawing paper, are hand-made.

MAKING BY HAND.

To form a sheet of paper by hand the workman takes a mould of wire-cloth with a moveable frame of wood called a deckle fitted all round it and extending slightly above its surface, and dips this mould into a vat containing the prepared pulp diluted with water, lifting up as much as will make a sheet of the necessary thickness. When the mould is removed from the vat the water drains through the wire-cloth, leaving the fibres on the surface, and the felting or intertwining of the fibres is assisted by lateral motion in every direction given by the workman to the mould. The deckle is then removed and the mould with the sheet of paper handed over to another workman, who turns it over on to a sheet of felt, by this means transferring the sheet

of paper from the wire to the felt. The sheets thus formed are piled together alternately with pieces of felt, and when a sufficient number have been made they are subjected to strong pressure to expel the water. The felts are removed and the sheets receive a second pressing. They are then sized by being dipped into a solution of gelatine, again slightly pressed, and finally hung up on lines made of horse hair to dry. If they are to have a smooth surface they are pressed through a calender.

Any pattern or name required on the paper, known as a water-mark, is obtained by means of a slightly raised pattern formed on the wire cloth, the consequence of which is that less pulp lodges there and the paper is slightly thinner, showing the counterpart of the pattern when held against the light.

MAKING BY MACHINE.

The paper-making machine is the invention of a workman named Robert, employed in a paper mill at Essones, in France, by M. Francois Didot. Didot set the apparatus to work, and Robert obtained a grant of 8,000 francs from the French Government and a patent for fifteen years. This was in 1799. In 1801 Didot came over to this country, and after obtaining two British patents sold them to Messrs. Fourdrinier, with whose name the machine is generally associated. A workshop in Dartford, in Kent, was selected as the place for making the machines, under the special care of Mr. Bryan Donkin. In 1803 a model of a self-acting machine was set up, in 1804 the system came successfully into use, and now there are in Great Britain about 550 paper machines at work, each producing probably on an average 20 tons of paper a week. One of the first engineering establishments in the world for building machines for paper-making is Messrs. Bertrams Limited, Sciennes, Edinburgh. This firm was founded over 70 years ago, and as an instance of its progress it may be mentioned that it turned out twelve paper-making machines in 1890, besides a large amount of general work, a production which has been hitherto unequalled by it or any other firm.

The paper-making machine of the present day, though embodying many ingenious improvements, differs little in principle from that originally constructed by Fourdrinier. It consists

essentially of an endless wire-cloth mould on to which the prepared pulp flows, and on which a continuous sheet of paper is formed. This is then passed through a series of rollers to expel the water, and over a number of heated cylinders to be dried, and is wound up at the end of the machine as finished paper.

The receptacles into which the pulp is passed on leaving the beaters are known as the stuff chests. They are provided with stirrers or agitators which continually revolve and keep the pulp constantly mixed with the diluting water.

From the stuff chests the pulp is pumped up into a small regulating box so constructed that the pulp in it remains constantly at the same level, thus insuring that the discharge of pulp on to the machine shall be uniform.

From this regulating box the pulp flows on to one end of a long shallow trough, termed a sand table, which is laid so that the pulp travels along it at a slow speed, allowing in its passage all particles of sand or dirt to fall to the bottom. In some mills these sand tables are 200 yards in length.

After leaving the sand tables the pulp passes through the strainers, which consist of strong brass or bronze plates with a number of very fine slits cut into them, and which remove all lumps formed by the intertwining of the fibre thus preventing inequalities in the finished paper. The slits vary from two to three inches long, and from about $\frac{1}{120}$ to $\frac{1}{20}$ of an inch in width. The strainers, when of the jog or cam motion type, receive a violent shaking motion to assist the passage of the fibres through the slits. But strainers with indiarubber suction diaphragms and revolving strainers are now much used.

From the strainers the pulp is passed on to the end of the wire-cloth, which is generally from 35 to 50 feet long and even as long as 60 feet in special cases, carried on a large number of small rolls. At each side is a strap of indiarubber, known as the deckle strap, which regulates the width of the paper. As the pulp travels along the wire the greater part of the water drains away, and passes into what is known as the save-all, but as this water contains a considerable quantity of the finer pulp particles, size, etc., it is pumped back again to the upper end of the sand tables and there used to dilute fresh pulp.

After the pulp has travelled about three-fourths of the length of the wire it passes over what are known as suction boxes, in which a vacuum is created by means of pumps (generally arranged in sets of two to six), and here the larger part of the remaining water is removed. The paper has now the consistence of wet blotting paper.

It then passes on the wire through a pair of rolls known as the couch rolls, which serve to press out water from the paper and to detach the paper from the wire. The paper is now received on to an endless felt, and passes through a pair of iron or brass rolls, known as the first press rolls. In doing this, one side being in contact with the metal roll is rendered comparatively smooth while the other retains the impress of the felt, and to make both sides alike the paper is passed through a second pair of press rolls, in which the side formerly in contact with the felt is brought in contact with the metal roll, and both sides of the paper are thus made alike. Sometimes the bottom press roll is covered with indiarubber to economise the felt.

After leaving the press rolls the paper is carried over the drying cylinders, which are heated with steam at a low pressure, from $2\frac{1}{2}$ to 20 pounds to the square inch. These may vary in number from eight to fifteen or twenty-two, each four feet in diameter, and are generally arranged in two groups, between which is placed a pair of chilled iron rolls, known as smoothers, and whose use is sufficiently indicated by the name.

If the paper is intended to be separately calendered it is now wound upon a reel and removed to the finishing house, but there is now a considerable demand for what are known as machine-finished papers, and there are therefore frequently attached one, two, three or four stacks of calenders to the end of the machine, by which the paper may be finished ready for use.

In some cases where an extra finish is desired, arrangements are made after the paper leaves the drying cylinders for passing it through damping rolls, where it is sufficiently wetted to enable it to take a high finish when passed through the calenders.

FINISHING PAPER AFTER LEAVING THE MACHINE.

The finishing house of a paper mill is fitted with calendering machines, which may either be web calenders for glazing con-

tinuous rolls or plate calenders for glazing single sheets, the latter being the type used for highly finished paper. Still higher degrees of finish are imparted by friction glazing, as for envelope papers, when wax is introduced in the process; also enamelled papers for special purposes.

There are in the finishing house cutting machines for cutting the webs up into sheets of different sizes, some of these machines being constructed to cut from as many as seven webs at one time. This class of cutter was first introduced by the late Mr. George Bertram, whose son, Mr. D. N. Bertram, is now Acting Director of Bertrams Limited.

The sheets are then sorted by hand, all damaged ones removed and the paper packed up and sent to market.

MACHINERY REQUIRED FOR MAKING PAPER.

The machinery necessary in a mill depends, of course, upon the quantity but quite as much upon the quality of paper intended to be made. Thus a mill with one paper-making machine to produce say 25 to 30 tons of a high-class writing or printing paper per week wholly from raw material, such as esparto, would require to be capable of dealing in the boiling with about 50 tons of esparto per week, and so would require two grass boilers.

For breaking there would be needed four large breaking engines, from which the half stuff would pass to the stuff chests of the presse pâte.

From the presse pâte the half stuff would be taken to the beaters, of which there would also be four of the large size.

Paper machines vary in width of wire from about 60 to about 126 inches, and the quantity of paper which can be produced on any machine may be said to be governed by the quality and the thickness of paper, the width of the wire and the heating power of the cylinders, because the greater the heating power the more rapidly can the paper be allowed to travel along the machine and, of course, the same course can be followed when a light paper is being made. Paper machines are therefore fitted with change wheels and also large tapered cones by which the speed can be regulated, and it may usually be varied from 30 to 200 feet per minute, and in the case of thin news paper to as much as about 250 to 300 feet per minute.

For steam power to drive such a mill Lancashire boilers working say at 80 to 100 pounds pressure and capable of supplying steam for about 450 indicated horse-power would be necessary.

The washing and beating engines would be best driven by one large compound engine of about 250 indicated horse-power, with a main shaft from which each washer or beater would be driven by a belt. The paper machine would be driven by a separate engine, or better still by two separate engines, one for the body of machine controlling the main line of paper, and the other to drive the back shafting for pumps and agitators of stuff chests, etc. Another engine would be required to drive the presse pâte, and smaller engines would also have to be provided to work the calenders, cutting machines, hoist, etc.

ARRANGEMENT OF PAPER MILLS.

A very great deal can be done in planning a mill to conduce to economy in working, and many schemes are adopted to suit special circumstances. For instance, the whole raw materials may be lifted by a hoist to the upper floor of a mill. The grass, in this case, after being picked, passes in at the top of the boilers, and after being boiled is withdrawn at the bottom to a floor on a lower level. Here, if necessary, it is wet picked, and passed to the breakers on the same level, the half stuff from which, after being bleached, flows down by gravitation into the stuff chests of the presse pâte. From these it is pumped up to the presse pâte machine, which in this case is on the same level as the beaters, and to which the pulp is removed in boxes on wheels. The beaters are generally placed on a slightly lower level than the breakers, so that if necessary the half stuff may flow directly into them from the breakers, without being passed over the presse pâte. The stuff chests of the paper machine are on a lower level than the beaters, so that the pulp again flows by gravitation into them, and the finishing house is generally on the same level as the machine house to avoid hoisting up the finished webs.

Each case, of course, presents special circumstances and must be dealt with on its merits. The principal points to be considered in choosing a site for a paper mill are the quality and quantity of the water supply, the facility with which the waste waters can

disposed of and the ease with which workers can be obtained, besides, of course, facilities of communication with markets for raw materials, chemicals, coals, and facilities for the transport of the finished paper.

WATER SUPPLY.

On the water supply the success of a mill may be said almost mainly to depend, 40,000 to 50,000 gallons of water being required for each ton of paper manufactured. Impurities in which iron forms an ingredient render a water supply very unsuitable for paper-making, but it is an unsettled point whether the presence of lime is objectionable or not.

For boiling and bleaching purposes it is objectionable to a certain extent, as giving rise when mixed with caustic soda or bleaching powder to precipitates of carbonate of lime, which form a hard scale on the inside of boilers and breakers, and this is liable to become detached and to find its way into the finished paper.

A somewhat curious instance of the effect which water has upon paper manufacture was mentioned to the author some time ago by a paper-maker in the west of Scotland. He had been in the habit of using water from a stream, which was collected in large settling ponds that the impurities might settle; but the supply being very abundant, and capable, if used in driving a turbine, of giving driving power equal to 40 horse power, he resolved to sink a well and use the water from this well for paper-making purposes. This he has done, with the result that he is now able to produce paper of a very much better colour than when he used the stream water, but he is met with the difficulty of matching the colour of paper which he formerly made, orders for which for such purposes as magazine printing were only partially complete, and this difficulty he found considerable.

EVAPORATION OF LIQUORS.

The getting rid of the liquors also sometimes presents considerable difficulties, as in the case of paper-mills on the North Esk. The usual plan adopted is to collect the washings from the boilers and the spent lye into tanks, reduce their bulk by evaporation until they are of a strength of about 15° Twaddle,

then burn off the woody and fibrous matters which they contain, and thus recover the carbonate of soda, which re-causticised by the addition of lime, is used along with the addition of a small quantity of fresh caustic soda, in the boiling of fresh grass.

Various evaporators have been introduced, some of them very primitive, consisting perhaps only of a furnace for incinerating the residue, and over it a pan containing the liquor, the latter being heated and evaporated by the heat from the furnace. With such an arrangement a large quantity of heat is wasted, and various patent evaporators have been introduced. It used to be considered that the most economical evaporator was that invented by M. Porion, a French distiller, and named after him. In this the liquor is run into a chamber in which a number of cast iron fanners dip into the liquor and revolve at the rate of about 300 revolutions a minute, producing and filling the chamber with a very fine spray, and presenting a very large evaporating surface.

Recently a method of evaporating *in vacuo*, invented by Mr. H. J. Yaryan, of Toledo, Ohio, U.S.A., has been considerably developed and has been largely used for the recovery of soda.

The other waste liquors are generally purified by simple downward filtration through ashes, and in some cases where the finer papers are made the washings from the machines, which contain a large proportion of fibre, are saved, and the residues dried and disposed of to the makers of brown papers.

CONCLUSION.

The subject of paper-making processes and machinery is such a very extensive one that to deal with it effectually a volume not a paper, would be necessary, and therefore in this paper it has only been possible to give a mere outline, and the author desires to acknowledge his indebtedness to Messrs. Cross and Bevan's "Test Book of Paper-Making" for much of the information here made use of.

DISCUSSION.

Mr. HENRY WEBB (Bury) said he was always sorry when the writer of a paper had to extol any foreign manufacture or process as better than our English practice. But he had good reason to believe the American Gould Engine process, alluded to by the author, was a failure, or to speak more correctly a comparative failure. By this he did not mean the machine would not do the work, but it would not do as much work as an English machine, because its first cost was greater, and it took more power to work it.

He was also sorry that the author had only alluded to the Scotch paper making trade, and to Scotch makers of paper machinery; surely with Manchester in the very centre of a large paper making industry there should have been no difficulty in getting information of what was being done at our very doors. As a Lancashire man, they would probably excuse him in telling them what was being manufactured in the immediate neighbourhood, in one class of paper alone, namely, news-paper. Over 1,000 tons per week were regularly made in the Manchester district, by such firms as Messrs. Chadwick & Taylor, Messrs. William Chadwick & Sons, The Darwen Paper Mill Co. Ltd., Star Paper Mill Co. Ltd., Sun Paper Mill Co. Ltd., Bury Paper Mill Co. Ltd., Messrs. Duxbury & Sons, Messrs. Gillespie & Mason, and others. It was also worth mentioning that the only tissue paper mills in Great Britain were in Lancashire, namely, Messrs. J. R. Crompton & Bros., of Bury, and R. Fletcher & Sons, of Ringley. The celebrated writing paper "W. T. & Co." was also made in Lancashire. The most successful maker of wood pulp paper for lithographic and other high class work was Mr. Partington, who, as was well known, had several mills in this district; and a kindred trade, paper staining wall papers, was extensively carried on in Manchester and the immediate neighbourhood, the largest makers being Potter & Co., of Darwen, they having their own large paper mills as well as staining works. Paper bag industry also flourished here, made by Messrs. Wild

& Sons, Messrs. Bibby & Baron, and others, and also a less developed trade of paper boxes for fancy cakes, mustard, starch, &c. Whilst for paper making machinery, Messrs. Bentley & Jackson, of Bury, were justly celebrated for their design and excellent workmanship. He might say the largest machines now in use were making a web of paper 120 inches wide, but Messrs. Bentley & Jackson were just building a machine for the Star Paper Co. Ltd., Blackburn, that would make a web of paper 135 inches wide. He believed that would be the largest paper machine yet made; his friend Mr. Jackson could tell them about this, and also what he had seen in his recent visit to the American paper mills.

The author had not said anything about beating engines. The various makes were, besides the ordinary open rag engine, the Umpherston, Brodie, Forbes, and Horne (all based on the principle of the old fashioned engine), and a host of refining engines known by the names of their inventors, such as the Kingsland, Jordan, Breitmann, Jeffers, and the Gould so highly extolled by the reader, but found wanting by its patrons in the United States. All were superseded by the Marshall.

It might be interesting to know that electric bleaching was being tried at Cardiff, but at present all attempts were in the experimental stage.

He would like to ask if any means had been devised for collecting and utilizing the electricity which was given off from the calender; he had frequently seen large sparks given off, and this at present went into the paper, necessitating its storing for a long time until the electricity was absorbed by the atmosphere, or the using of artificial means for extracting it. This process was called "conditioning."

Mr. JOSEPH ADAMSON made a few comments on the small circular saws referred to in the paper, and stated that exceedingly fine saws were made by Messrs. Paget & Co., Loughborough.

Mr. HANS RENOLD asked if Mr. Rea could tell them how many tons of news-paper were produced weekly in Scotland, in Lancashire, and in the South of England. He might say that some years since, when in Italy, he saw some breaking and

beating engines which were made of one block of white marble, they were about 16ft. long by 14ft. wide, and he did not think that this size, though made in stone, could be much surpassed by English engines made of cast iron and of several parts. Of course, size was no measure of efficiency. It might be interesting to the members if Mr. Rea could state any particulars respecting the industrial geography of paper making in the British Islands.

Mr. JACKSON (Bentley & Jackson, Paper Maker's Engineers, Bury) said he had listened with very much pleasure to the interesting paper read by Mr. Rea, the more so because he (Mr. Jackson) was in some measure connected with the paper trade through his business as a maker of paper mill machinery.

He had not, however, contemplated making any remarks or joining in the discussion, as he was indebted to their courtesy and the kind invitation of his friend Mr. Webb for his visit there that evening.

He would have liked to have heard this matter discussed by practical paper makers, but as most of them were he presumed either designers of or constructors of machinery, they must of necessity look at it from their own, *i.e.* the engineers' side of the question. The machinery used to-day in the various processes of paper-making was practically of the same design as that in use for generations past. It had been modified and improved in detail to suit the various fibres used in these days and affected by the general advance in mechanical science and workmanship, but the methods were nearly similar; curiously, few of these processes were due to the professional engineer, but rather to paper makers and others of an inventive mind. Probably the reason was not difficult to find, but this was hardly the occasion to enlarge on that point.

One of the recent improvements was in machinery for cutting rags, rope and other heavy and dusty material; there were two machines now well introduced, one for light work called the Coburn-Taylor machine, the other for heavy work known as the Nuttall machine, by which the materials were cut more rapidly and better and cheaper than by any other known machine. Another modern machine had for its object the removal of

portions of rags to which buttons were attached, pieces of wood and similar objectionable matters; this however had not been much applied, as the introduction of other fibres had considerably reduced the demand for rags, excepting for high class papers.

The machine described as being used for washing and breaking, bleaching and beating, had its origin in the Low countries and was commonly known on the continent as "The Hollander." This machine was nearly the same in design as when it left the Dutchman's hands; it was made larger, of iron instead of wood, and was improved in its detail. The great majority of practical paper makers maintained that nothing had yet been constructed to superseded the old-fashioned Hollander. It was, however, admitted that the pulp produced by it was not satisfactory, and many inventors had endeavoured to solve this difficulty.

Americans had displayed the greatest activity in this direction, and had produced various refining engines, the best up to recent date being the Kingsland, and Jordan and Gould, named after their respective inventors; of these the Jordan was most successful, but each had very marked imperfections. A few years ago a young paper maker named Marshall, after thoroughly studying the subject, conceived the idea of uniting the two best engines, the Jordan and the Gould, by passing the material first through the Jordan cone to grind or refine it, and secondly through the Gould disc to "clear" the knots which might be formed in the Jordan. This combination had proved very successful, and when used in conjunction with the Hollander was found to produce paper pulp at less cost, and to make a more even, regular and stronger sheet of paper with a less expenditure of power than absorbed by the Hollander alone.

The success of this engine had been phenomenal, and it seemed as if it would prove the only really perfect machine for this purpose.

Mention had been made of a large machine now in course of construction for the Star Paper Mill Co. Ltd., Blackburn, by his firm as the largest in the world. A few details of this mammoth machine, as some of his American friends had named it, might be of interest. It was intended for the manufacture of ordinary news-paper, such as used by our local papers, the

Guardian, Courier, etc., and will be wide enough to make a finished web of paper 135 inches wide, that was three webs each 45 inches wide for the printing press. The paper pulp will be prepared in the ordinary way and refined by a Marshall engine, and delivered to the pulp chest or cistern. It will then pass through four revolving strainers of the Reinicke & Jasper type, from which it will flow to an endless wire, 40 feet long, 145 inches wide; this wire was carried by a number of seamless brass and copper tubes, varying from 4 inches to 20 inches diameter. The rolls for squeezing and pressing the moisture from the web were made of cast brass and chilled iron, about 20 inches diameter, 12 feet long. The drying portion of the machine consisted of cast-iron cylinders, each 5 feet diameter, 12 feet long, to be heated by steam pressure; they were bored through and turned to ensure an even thickness of metal, the ends being of cast iron covered with steel baffle plates to prevent radiation. The felt carrying rolls were of welded steel 9 inches diameter, the ends were welded in and the whole turned and polished. Cylinders of less diameter but of similar construction were used for drying the felts which held the wet web of paper against the faces of the drying cylinders The smoothing rolls or calender were to be of solid chilled iron, from 22 inches to 14 inches diameter, all 142 inches long on the face. The whole of the rolls and the drying cylinders will be highly polished by corandum wheels in a "buffing machine." The driving gear for the various sections of the machine was of the kind known as the Marshall driving train, the adjustments in speed being made by moving the driving straps or belts on slightly conical belt pulleys. The entire machine will be driven by a pair of high-pressure inverted steam engines, each cylinder 15 inches diameter, prepared for a piston stroke of 18 inches, and making 120 revolutions per minute. He estimated the total weight of this machine will be 350 tons. The production of paper will of course depend on the skill and ability of the attendants, but he thought it might, without exaggeration, be assumed to be capable of making 135,000lbs. weight per week.

Mr. Webb's remarks as to the utilisation of the electricity produced by calendering paper on the paper machine reminded him of a little electric apparatus he had introduced into this

country from the United States, for the purpose of extracting particles of iron from paper pulp and preventing it from appearing in the dry paper. The pulp was made to flow in a thin stream over one or more bar magnets, excited by a current from a small dynamo. The attractive power of the magnet withdrew any large or small particle of iron from the pulp and retained it in contact with the magnet until the machine was stopped, when the magnets were cleaned. So-called permanent magnets had been tried for this purpose with temporary success, but as the attractive power of the magnet diminished so the evil recommenced, and their use was abandoned.

The presence of iron was of little importance in low qualities of paper, but was very objectionable in writing papers, and high class papers for lithographic and printing purposes.

With reference to his recent visit to America, he could not speak too highly of the kind reception he had received from those members of the Paper Making and Engineering trades with whom he was brought in contact, for which he was deeply grateful, as it tended to make his visit more pleasant and instructive than it otherwise would have been. He also formed the opinion that British paper makers must look into matters closely if they intended to retain their foreign trades. American paper makers already made attacks on our Colonial markets, and in one instance he knew of, that attack had been so keenly felt that the British paper mill affected had sent their manager to see by what means the Americans were able to produce a better paper at the selling price, whether it be by improved machinery or by more skilful use of material. He awaited the result of the manager's visit, and looked forward to the report with much interest. Whatever it might be he was sure nothing but a good result could accrue from a visit made for such a purpose, if undertaken by an open minded and unprejudiced man.

Mr. FRANCIS WRIGLEY gave a few reminiscences of paper making.

The CHAIRMAN (Mr. T. Ashbury, Past-President) observed that he thought they had been all greatly pleased by the interesting

paper which had been read by Mr. Rea on behalf of his friend in Edinburgh.

On the motion of the CHAIRMAN, a cordial vote of thanks was passed by acclamation to Mr. J. B. Bennett for the instructive manner in which he had written the paper, and to Mr. Alex. Rea for the effective way in which he had communicated it to the meeting; and also to Messrs. Bertrams, Ltd., Edinburgh, for their kindness in forwarding for inspection the various samples of pulp, chemicals, etc., to illustrate the paper.

Mr. ALEX. REA, in replying, said that, not being the author of the paper, he had not quite so free a hand as he should have liked. At the same time he had no fault to find, generally speaking, with the remarks which had been made.

Mr. Webb, he fancied, had fallen into a slight misapprehension as to the meaning of the reader's casual remarks on the Gould beating engine, the word extol being an exaggeration of the matter. Having had some experience with this engine for fining purposes in beating pulp, he found it was a new departure which gave at least promise of better things. Hence the allusion, which was practically corroborated by Mr. Jackson, who stated that the Jordan and Gould engine when "Marshalled" made a splendid combination, and that they had had a success which was quite phenomenal. That at least justified what was said, and was a reply to Mr. Webb's remarks on that point.

It was no doubt a delicate matter to hint that they were somewhat conservative or antiquated in their ideas on the subject of paper making, or, for the matter of that, on any other topic. It must be admitted, however, that our Trans-Atlantic cousins were not behindhand, as Mr. Webb had told them in his excellent paper on the manufacture of iron. Then they were all aware that Mr. Renold would even go further than Mr. Webb as to progressive ideas in the States.

He must confess that the paper did not treat of all the machines as made by the different makers for the manufacture of paper, as that would have been a very big subject. It must be admitted, however, that the author had given a very clear, lucid, and concise description of the art of paper making.

In reference to the query of collecting the electricity from the glazing rolls, it would be admitted that this would be a most interesting study. So far, however, he believed it was in the region of undeveloped science. Possibly some of our electric friends might take the hint. Referring to the question noted by Mr. Adamson as to the small saws for cutting the strainer plates, it was well known that our Continental friends were very successful in making saws for such purposes. He was pleased to learn, however, that in this branch of industry we were able to hold our own.

Replying to Mr. Renold, he had not sufficient or reliable data to answer his question, though from his point of view it might be interesting. At the same time, it was more statistical than technical. Mr. Renold, therefore, would see the matter was not one of primary importance.

He now came to their good friend Mr. Jackson, who had contributed in no small measure to the success of the paper. Personally he thanked him for the excellent and interesting remarks on this important subject, which would make a valuable contribution to the essay. It would be conceded that, after the able speeches of our Bury friends, the absence of practical paper makers would not be so much felt. He would take the liberty of saying that it was from no want of courtesy that he had not been in communication with a Lancashire firm *re* this essay on paper making, but simply from want of intimacy. It would be seen, therefore, how the partial localisation of the matter took place.

In conclusion, Mr. Rea expressed his appreciation for the cordial way in which the paper had been received, and on behalf of the author sincerely thanked them for the vote of thanks passed to that gentleman. Personally, the privilege and opportunity of addressing them, more than compensated for the trouble incurred in bringing the same paper the Association.

COMPARISON OF FRICTION IN COTTON MILL ENGINES AND GEARING TO THE ACTUAL WORK DONE.

BY

MR. ALFRED SAXON,

OF MANCHESTER.

SATURDAY, 22ND OCTOBER, 1892,

In bringing this subject before your notice I feel it is one that is deserving of our attention, and it is hoped that it will be the means of enabling us to do something to prevent the loss of power and economy which exist in Engines and Gearing at the present time from this cause.

Thurston says "Friction is a resistance which is always" "met when two bodies or particles, whether solid, liquid or" "gaseous, are compelled to move, one upon another. There are" "three kinds of friction, so called; rolling and sliding with" "solids, and fluid friction with liquids and gases. These are all" "governed by different laws, and with each the statement of" "those laws as usually given in the text books probably require" "some modification." It is not my intention to attempt to analyze the different kinds of friction created in Engines and Gearing; I shall deal with all kinds of friction under the general head of Friction. It will also be impossible for me to furnish minor details of such Engine and Gearing arrangements which may be referred to, as time and space will be occupied in a general description.

I have not been successful in obtaining permission to indicate some of the Engines I had intended, and in one or two cases of refusal, perhaps the least said, the better. You will no doubt agree with me that running large Engines up to their working speed without weight on is not a very desirable thing, and is occasionally productive of hot bearings, which is probably the true explanation of consent being witheld in some instances.

In the examples which will be referred to, it has not been attempted to select very extreme cases, such as do exist, but I have tried to select examples which will fairly illustrate Mill Engines

and Gearing which have been constructed within a comparatively recent date. Economies are being effected in Steam Engines at the present time by utilising higher pressures of steam, but we shall not be long in reaching a safe working limit in that direction.

There is no doubt that along with this increase of pressures, we have had an increase of speeds in Engines and Gearing. We, as an industrial people are drawing rapidly upon the coal supply, and if we must leave coal for the use of the generations yet unborn, and at the same time cheapen the cost of our productions, we must in our different positions as practical Engineers, Consulting Engineers and Mill Architects, in drawing up specifications and carrying them out, use every available means of improving the efficiency of the Engines and Gearing of our manufactories. There are a variety of ways of judging of the economy of steam Engines and Gearing, the commonest being the number of lbs. of coal per indicated horse power per hour, another test being that of the weight of steam used; these however are only partial tests. The test which many Mill owners apply in a rough and ready sort of way, that of reckoning the number of spindles of either twist or weft, or both, and the counts of the yarn and the weight spun for a given quantity or value of coal, in comparison with their neighbours who have similar mills, is a good proof of economical working, if taken into consideration with the tests above mentioned.

In the term "Actual work," in the examples given, I wish it to be understood that I include all the power absorbed in driving the machinery itself, and the work done by the machinery as "Actual work."

If the coal consumption were based on the actual work done it would give some startling results, as is shown by a study of the following examples :—

SPUR GEARING ENGINES.

1st Example.—Pair of horizontal compound tandem engines with high pressure cylinders 24in. diameter, low pressure cylinders 48in. diameter, all 5ft. 6in. stroke, making 51 revolutions per minute, or a piston speed of 561 feet per minute.

Fly spur driving wheel 14ft. 6½in. diameter, 5in. pitch,

18½in. broad, 110 teeth; pinion 6ft. 7in. diameter, 50 teeth. Rim speed, 2,324 feet per minute.

Indication with full load, and boiler pressure of 110lbs. works out to 1,309·6 indicated horse power.

Indication of friction load with the whole of the Gearing and Engines at work equals 385·76 indicated horse power, being 29·47 per cent. of the total load, leaving an actual load of 70·53 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals — 21·2lbs. Average pressure referred to low pressure cylinder for friction load equals —6·2lbs.

Description of Gearing: wheel and rope driving, partly new and partly old, not supplied by engine maker.

2nd Example.—Pair of horizontal compound tandem engines with high pressure cylinders 21in. diameter, low pressure cylinders 42in. diameter, all 6ft. stroke, making 35½ revolutions per minute, or a piston speed of 426 feet per minute.

Fly spur driving wheel 19ft. diameter, 4⅞in. pitch, 16in. broad, 150 teeth; pinion 6ft. 6in. diameter, 51 teeth. Rim speed 2,119 feet per minute.

Indication with full load and boiler pressure of 110lbs works out to 989·54 indicated horse power.

Indication of friction load with the whole of the Gearing and Engine at work equals 217·49 indicated horse power, being 22 per cent. of the total load, leaving an actual load of 78 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals — 27·73lbs. Average pressure referred to low pressure cylinder for friction equals —6·02lbs.

Description of Gearing: wheel and rope driving new, not supplied by engine maker.

3rd Example.—Pair of horizontal compound side-by-side engines, with high pressure cylinder 16in. diameter, low pressure cylinder 28in. diameter, both 4ft. stroke, making 70 revolutions per minute, or a piston speed of 560 feet per minute.

Fly spur driving wheel 10ft. 11½in. diameter, 3in. pitch, 10in. broad, 188 teeth; pinion 7ft. 5in. diameter, 94 teeth. Rim speed 2,410 feet per minute.

Indication with full load, and boiler pressure of 80lbs. works out to 250 indicated horse power.

Indication of friction with the whole of the Gearing and Engines at work equals 87·62 indicated horse power, being 33·2 per cent. of the total load, leaving an actual load of 66·8 per cent. for the engine.

Description of Gearing: old. *P.S.*—The friction at 64 revolutions per minute equals 78·17 indicated horse power.

4th Example.—Pair of horizontal compound side-by-side engines, with high pressure cylinder 30in. diameter, low pressure cylinder 54in. diameter, both 6ft. stroke, making 41 revolutions per minute, or a piston speed of 492 feet per minute.

Fly wheel 19ft. diameter, spur driving wheel 15ft. 0½in. diameter, 5in. pitch, 16in. broad, 114 teeth; pinion 5ft. 5½in. diameter, 41 teeth. Rim speed 2,025 feet per minute.

Indication with full load with a boiler pressure of 65lbs. works out to 802·6 indicated horse power.

Indication of friction load with the whole of the Gearing and Engines at work equals 285·5 indicated horse power, being 35·6 per cent. of total load, leaving an actual load of 64·4 per cent. on the engines.

Indication of friction load of engines only equals 82·9 indicated horse power, being 10·3 per cent. of total load, leaving an actual load of 89·7 per cent. to be transmitted through the crank shaft. Average pressure referred to low pressure cylinder for full load equals 22·4lbs.

Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 7·9lbs. Average pressure referred to low pressure cylinder for friction of engines only equals 2·8lbs.

Description of Gearing: wheel and rope driving.

The power is distributed as follows: one weaving shed driven by wheels; one weaving shed driven by wheels, followed by ropes; one card room driven by ropes, followed by wheels.

5th Example.—Pair of horizontal triple-expansion tandem engines, with high pressure cylinders 14½in. diameter, intermediate cylinders 28in. diameter, low pressure cylinders 36½in. diameter, all 6ft. stroke, making 51 revolutions per minute, or a piston speed of 612 feet per minute.

Fly spur driving wheel 14ft. 8⅛in. diameter, 4⅛in. pitch, 18in. broad, 115 teeth; pinion 6ft. 7⅛in. diameter, 52 teeth. Rim speed 2,356 feet per minute.

Indication with full load with boiler pressure of 160lbs. works out to 1,044·5 indicated horse power.

Indication of friction with the whole of the Gearing and Engines at work equals 205·95 indicated horse power, being 19·7 per cent. of the total load, leaving an actual load of 80·3 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 26·9lbs. Average pressure referred to low pressure cylinder for friction load of gearing and engines equals 5·3lbs.

Description of Gearing: wheel gearing throughout.

P.S.—Engines formerly compound. Recently tripled.

6th Example.—Pair of horizontal compound side by side engines, with high pressure cylinder 27in. diameter, low pressure cylinder 48in. diameter, both 5ft. stroke, making 50¼ revolutions per minute, or a piston speed of 502·5 feet per minute.

Spur driving wheel 18ft. diameter, 5in. pitch, 15in. broad, 98 teeth; fly-wheel 18ft. diameter; pinion 6ft. 3¼in. diameter, 48 teeth. Rim speed of 2,050 feet per minute.

Indication with full load with a boiler pressure of 100lbs. works out to 840·55 indicated horse power.

Indication of friction with the whole of the Gearing and Engines at work equals 201·45 indicated horse power at 45 revolutions per minute, being 24 per cent. of total load, leaving an actual load of 76 per cent. on the engines.

Indication of friction load of engines at 50¼ revs. only equals 50·85 indicated horse power, being 6 per cent. of total load, leaving an actual load of 94 per cent. to be transmitted through the crank shaft.

Average pressure referred to low pressure cylinder for full load equals 30·6lbs. Average pressure for low pressure cylinder for friction load of gearing and engines equals 7·3lbs. Average pressure referred to low pressure cylinders for friction load of engines only equals 1·8lbs.

Description of Gearing: on the end of the 2nd motion shaft there is a rope pulley having 12 ropes and driving about 390 indicated horse power, the rest of power is distributed by wheels.

7th Example.—Pair of horizontal compound tandem engines, with high-pressure cylinders 24in. diameter, low pressure cylinders 48in. diameter, both 6ft. stroke, making 36 revolutions per minute, or a piston speed of 432 feet per minute.

Fly spur driving wheel 21ft. diameter, 5½in. pitch, 18in. broad, 140 teeth, pinion 7ft. diameter, 47 teeth. Rim speed 2,375 feet per minute.

Indication with full load with a boiler pressure of 100lbs. works out to 1,008 indicated horse power.

Indication of friction load with the whole of gearing and engines at work equal 268 indicated horse power, being 26 per cent. of the total load, leaving an actual load of 74 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 21lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 5·51bs.

8th Example.—Pair of compound Mc.Naught's beam engines, high pressure cylinders 35in. diameter, by 3ft. 6in. stroke, low pressure cylinders 42¼in. diameter by 7ft. stroke, making 33 revolutions per minute, or a piston speed of 462 feet per minute for the low pressure pistons.

Fly spur driving wheel 25ft. diameter, 4¼in. pitch, 16in. broad, 210 teeth, pinion 6ft. 1in. diameter, 51 teeth. Rim speed 2,590½ feet per minute.

Indication with full load with a boiler pressure of 90lbs. works out to 1,150 indicated horse power.

Indication of friction load with the whole of Gearing and Engines at work equals 208 indicated horse power, being 18·17 per cent. of the total load, leaving 81·83 per cent. of an actual load on the engine.

Average pressure referred to low pressure cylinder for full load equals 22·88lbs. Average pressure referred to low pressure cylinder for friction load of gearing and engines equals 7·91bs.

Description of Gearing: wheel gearing throughout; mule-driving direct from line shafts.

9th Example.—Pair of triple-expansion engines with four cylinders, one high pressure 28½in. diameter, one intermediate pressure 85½in. diameter, one low pressure 89in., and one low pressure 48$\frac{15}{16}$in., all 6ft. stroke, making 85½ revolutions per minute, or a piston speed of 426 feet per minute.

Fly spur driving wheel 19ft. 10½ins. diameter, 5½in. pitch, 19in. broad, 140 teeth; pinion 5ft. 11½in. diameter, 42 teeth. Rim speed 2,218·5 feet per minute.

Indication with full load with boiler pressure of 160lbs. works out to 1,145 indicated horse power.

Indication of friction load with the whole of Gearing and Engines at work equals 300 indicated horse power, being 26·2 per cent. of the total load, leaving an actual load of 73·8 per cent. on the engine.

Average pressure referred to low pressure cylinder for full load equals 33·3lbs. Average pressure referred to low pressure for friction load of engines and gearing equals 8·7lbs.

Description of Gearing: wheel gearing throughout.

P.S.—Formerly compound, recently tripled.

10th Example.—Pair of compound Mc.Naught's beam engines, high pressure cylinders 35in. diameter by 8ft. 6in. stroke, low pressure cylinders 46in. diameter by 7ft. stroke, making 29 revolutions per minute, or a piston speed of 406ft. per minute for the low pressure pistons.

Fly spur wheel 15ft. 3⅜in. diameter, 6in. pitch, 15in. broad, 96 teeth; pinion 5ft. 10in. diameter, 37 teeth. Rim speed 1,392 feet per minute. Separate fly wheel.

Indication with full load at boiler pressure of 64lbs. works out to 821·26 indicated horse power.

Indication of friction load with the whole of Gearing and Engines at work equals 207·96 indicated horse power, being 25·3 per cent. of the total load, leaving 74·7 per cent. of an actual load on the engines.

Average pressure referred to low pressure cylinder for full load equals 20lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 5·09lbs.

ROPE DRIVING ENGINES.

1st Example.—Pair of horizontal compound side by side engines, high pressure cylinder, 32in. diameter, low pressure cylinder, 60in. diameter, both 7ft. stroke, making 52 revolutions per minute, or a piston speed of 728 feet per minute.

Rope pulley 34ft. diameter, grooved for 32 ropes. Speed of ropes 5,554·8 feet per minute.

Indication with full load with boiler pressure of 94lbs. per square inch work out to 1,272 indicated horse power.

Indications of friction load with the whole of the gearing and engines at work equals 296 indicated horse power, giving 23·3 per cent. of total load, leaving 76·7 per cent. of an actual load on the engine. Friction at 50 revolutions equals 270·3 indicated horse power.

Average pressure referred to low pressure cylinder for full load equals 18·4lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 4·3lbs.

Gearing new but not made by engine maker.

2nd Example.—Horizontal compound tandem engine, high pressure cylinder 22in. diameter, low pressure cylinder 44in. diameter, stroke 5ft., making 58½ revolutions per minute or a piston speed of 585 feet per minute. Rope pulley 28ft. diameter, grooved for 16 ropes, 1¼in. diameter, 10 ropes only being used. Speed of ropes, 5,146·9 feet per minute.

Indication of full load with boiler pressure of 100lbs. works out to 724·9 indicated horse power.

Indications of friction with the whole of gearing and engines at work equal 232·1 indicated horse power giving 32 per cent. of friction, leaving an actual load of 68 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 23·9lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 8·6lbs.

Description of Gearing: New, but badly arranged to assist in driving part of another mill. 24 ropes 1¼in. diameter used in driving in addition to main shafts.

Not supplied by engine maker.

3rd Example.—Pair of horizontal compound side by side engines, high pressure cylinders 24in. diameter, low pressure cylinders 48in. diameter, both 5ft. 6in. stroke, making 62 revolutions per minute or a piston speed of 682 feet per minute.

Rope pulley 24ft. diameter, grooved for 24 ropes 1¼in. diameter, speed of ropes 4,674·7 feet per minute.

Indications of full load with boiler pressure of 110lbs. work out to 859 indicated horse power.

Indications of friction load with the whole of gearing and engines at work equal 274·2 indicated horse power giving 32·8 per cent. of total load, leaving an actual load of 67·2 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 28lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 7·8lbs.

Description of Gearing: Old, altered to suit rope driving; was previously arranged for belt driving.

4th Example.—Pair of horizontal compound tandem engines, with high pressure cylinders 22in. diameter, low pressure cylinders 44in. diameter, all 5ft. stroke, making 55 revolutions per minute or a piston speed of 550 feet per minute.

Rope pulley 28ft. diameter grooved for 28 ropes 1¼in. diameter, speed of ropes 4,838 feet per minute.

Indications of full load with boiler pressure of 90lbs. work out to 1,025 indicated horse power.

Indications of friction with the whole of gearing and engines at work equal 324·93 indicated horse power giving 31·7 per cent. of the total load, leaving an actual load of 68·3 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 22·6lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 6·4lbs.

Description of Gearing: New, not supplied by engine maker.

5th Example.—Pair of horizontal compound tandem engines, with high pressure cylinders 20in. diameter, low pressure cylinders 40in. diameter, all 5ft. stroke, making 60⅓ revolutions per minute or a piston speed of 603⅓ feet per minute.

Rope pulley 28ft. diameter grooved for 26 ropes 1¼in diameter, speed of ropes 5,306 feet per minute.

Indications of full load with a boiler pressure of 90lbs. works out to 978·25 indicated horse power.

Indications of friction with the whole of the gearing and engines at work equal 283 indicated horse power, giving 28·9 per cent. of total load, leaving an actual load of 71·7 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 21·4lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 6·2lbs.

Description of Gearing: New, not supplied by engine maker.

6th Example.—Pair of horizontal compound tandem engines, with high pressure cylinders 20in. diameter, low pressure cylinders 40in. diameter, all 5ft. stroke, making 57 revolutions per minute or a piston speed of 570 feet per minute.

Rope pulley 28ft. diameter grooved for 24 ropes 1¼in. diameter. Speed of ropes 5,013·9 feet per minute.

Indications of full load with a boiler pressure of 90lbs. works out to 992·96 indicated horse power.

Indications of friction load with the whole of the gearing and engines at work equal 310·1 indicated horse power, giving 31·2 per cent. of the total load, leaving an actual load of 68·8 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 22·9lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 7·1lbs.

Description of Gearing: New, not supplied by engine maker.

7th Example.—Horizontal compound tandem engine, high pressure cylinder 19in. diameter, low pressure cylinder 38in. diameter, 5ft. stroke, making 62 revolutions per minute or a piston speed of 620 feet per minute.

Rope pulley 21ft. diameter, grooved for 16 ropes, 1¼in. diameter. Speed of ropes 4,092 feet per minute.

Indication with full load with a boiler pressure of 100lbs. works out to 393·5 indicated horse power.

Indications of friction load with the whole of gearing and engine at work equal 126·8 indicated horse power, being 32·3 per cent. of the total load, leaving an actual load of 67·7 per cent. on the engine.

Average pressure referred to low pressure cylinder for full load equals 18·51lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 5·91lbs.

8th Example.—Pair of horizontal compound tandem engines, high pressure cylinders 27in. diameter, low pressure cylinders 46in. diameter, all 5ft. 6in. stroke, making 75 revolutions per minute or a piston speed of 825 feet per minute.

Rope pulley 22ft. diameter grooved for 40 ropes 1¼in. diameter. Speed of ropes 5,188·6 feet per minute.

Indication with full load with a boiler pressure of 100lbs. works out to 1,579·52 indicated horse power.

Indications of friction with the whole of gearing and engines at work equal 389·4 indicated horse power, being 24·6 per cent. of the total load, leaving 75·4 per cent. of an actual load on the engines.

N.B.—This engine is not fully loaded; the shafting and engines were fixed to turn 2,000 indicated horse power. The friction at this power equals 19·47 per cent.

New Gearing supplied by the maker of engines.

BELT DRIVING ENGINES.

1st Example.—Pair of horizontal compound tandem engines, with high pressure cylinders 18in. diameter, low pressure cylinders 36in. diameter, all 5ft. stroke, making 53 revolutions per minute or a piston speed of 530 feet per minute. Fly-belt pulley 26ft. diameter, 8ft. wide, for three belts 2ft. 6in. wide, giving a belt speed of 4,320 feet per minute.

Indication with full load with boiler pressure of 100lbs. equals 855·95 indicated horse power.

Indication of friction load with the whole of the gearing and engines at work equals 241·85 indicated horse power, being 28·2 per cent. of the total load, leaving an actual load of 71·8 per cent. on the engines.

P.S.—There is some rope driving, gearing supplied by maker of engines.

2nd Example.—Pair of horizontal compound tandem engines, with high pressure cylinders 26in. diameter, low pressure cylinders 40in. diameter, all 5ft. stroke, making 47¼ revolutions per minute or a piston speed of 472½ feet per minute.

Fly-belt pulley 28ft. diameter, 7ft. wide, prepared for three belts each 26in. in width, and giving a belt speed of 4,158 feet per minute.

Indication of full load with a boiler pressure of 85lbs. works out to 969 indicated horse power.

Indication of friction with the whole of the gearing and engine at work equals 262·3 indicated horse power being 27 per cent. of the total load, leaving an actual load of 73 per cent. on the engines.

Average pressure referred to low pressure cylinder for full load equals 20·8lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 7·5lbs.

DIRECT-ACTING ENGINES.

1st Example.—Horizontal single cylinder condensing engine, with cylinder 32in. diameter, stroke 3ft., making 91 revolutions per minute or a piston speed of 546 feet per minute.

Indication of full load with boiler pressure of 80lbs. works out to 503·85 indicated horse power.

Indication of friction with the whole of the gearing and engine at work equals 99·1 indicated horse power, being 19·67 per cent. of total load, leaving an actual load of 80·33 per cent. on the engine.

Average pressure referred to low pressure cylinder for full load equals 30·7lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 7·4lbs.

P.S.—The Gearing in this case is old.

2nd Example.—Inverted vertical three throw crank triple expansion engine, with high pressure cylinder 14in. diameter intermediate 22½in., low pressure 36in. diameter, all 3ft. 6in. stroke, making 65½ revolutions per minute or a piston speed of 458½ feet per minute.

Crank shaft coupled direct to second motion shaft.

Indication with full load with boiler pressure of 195lbs. works out to 338·8 indicated horse power.

Indications of friction load with the whole of the gearing and engine at work equal 94·5 indicated horse power at 68 revolutions per minute, being 28 per cent. of total load, leaving an actual load of 72 per cent. on the engines.

(Description continued on page 182.)

SUMMARY.

SPUR GEARING.

	Full Load. I. H. P.	Average Pressure referred to, L.P. cyl.	Friction Load. I. H. P.	Average Pressure referred to, L.P. cyl.	Percentage of friction to total load.	Actual work done.	Rim Speed, feet per min.	Revs. of Engine
1st Example	1309	21·2	385·76	6·2	29·47	70·53	2324	51
2nd ,,	989·54	27·73	217·49	6·02	22	78	2119	35½
3rd ,,	250	24	87·62	4·3	33·2	66·8	2410	70
4th ,,	802·6	22·4	285·5	7·9	35·6	64·4	2025	41
5th ,,	1044·5	26·9	205·95	5·3	19·7	80·3	2356	51
6th ,,	840·55	30·6	201·45	7·3	24	76·0	2050	50
7th ,,	1008	21	263	5·5	26	74	2375	36
8th ,,	1150	22·88	209	7·9	18·17	81.83	2590	33
9th ,,	1145·1	33·3	300·27	8·7	26·2	73·8	2218	35½
10th ,,	820·26	20	207·96	5·09	25·3	74·7	1392	29
Giving an average of ..					25·964	74·036		

ROPE DRIVING.

							Speed of Ropes in feet per min.	Diam. of Ropes
1st Example	1272	18·4	296	4·3	23·3	76·7	5,543	1½
2nd ,,	724·9	23·9	232·1	8·6	32	68	5,146	1¾
3rd ,,	859	23	274·2	7·3	32·8	67·2	4,674	1½
4th ,,	1025	22·6	324·93	6·4	31·7	68·3	4,840	1¾
5th ,,	978·25	21·4	283	6·2	28·9	71·1	5,306	1¼
6th ,,	992·9	22·9	310·1	7·1	31·2	68·8	5,013	1¾
7th ,,	393·5	18·5	126·8	5·9	32·3	67·7	4,092	1¾
8th ,,	1579·52	19	389·4	4·7	24·6	75·4	5,183	1⅜
Giving an average of ..					29·6	70·4		

BELT DRIVING ENGINES.

							Speed of Belts in feet per min.
1st Example	855·95	26·1	241·85	7·3	28·2	71·8	4,329
2nd ,,	969	20·8	262·3	7·5	27	73	4,158
Giving an average of ..					28·6	72·4	

DIRECT-ACTING OR DIRECT-COUPLED ENGINES.

1st Example	503·85	30·7	99·1	7·4	19·67	80·33	
2nd ,,	338·8	23·1	94·5 at 68 revs.	6·4	28	72	
Giving an average of ..					23·835	76·165	

Average pressure referred to low pressure cylinder for full load equals 23·1lbs. Average pressure referred to low pressure cylinder for friction load of engines and gearing equals 6·4lbs. Average pressure referred to low pressure cylinder for friction load of engines only equals 1·916lbs.

P.S.—The engines were put in for driving a considerably heavier load. The gearing in this mill is old and badly arranged from engine. Inside the mill some of the line shafts are driven by main belts, which are very short and have to be very tight. In some cases one belt is mounted upon another to secure sufficient adhesion for driving the load.

The conclusions to be drawn from the examples furnished, although not numerous and varied enough to pronounce a definite and accurate opinion upon, point to the fact that the engines would be found to be fairly efficient in themselves, but that the arrangement, construction, and the lubrication of the gearing is the principal defect. Three Examples given in the following table will prove this point:—

Examples of Friction of Engines only.

Example.	Full load indicated horse power.	Average pressure referred to low pressure for full load.	Friction load indicated horse power engines only.	Average pressure referred to low pressure for friction load of engines.	Per cent. of friction of engines only to total load.	Per cent. of actual work transmitted through crank shaft.
No. 4 in Spur Gearing	802·6	22·4	82·9	2·3	10·3	89·7
No. 6 Spur Gearing	840·55	30·6	50·85	1·8	6	94
No. 2 in direct coupled	338·8	23·1	28·1	1·916	8·294	91·706

The friction diagrams in example 4 in the above table, were taken from a new engine within an hour from the engine being started, when everything was stiff, &c.

The power in examples 4 and 6 above is transmitted first by spur fly driving wheel and pinion, afterwards rope driving is introduced; the friction of the gearing only being 25·8 per cent. and 18 per cent. respectively; the friction of the engines and gearing together being 35·6 per cent. and 24 per cent. respectively of the total load.

In example 2 in direct-coupled in above table, the power is transmitted direct, the second motion shaft being coupled to crank shaft and afterwards distributed by gearing and belt driving, which is old and badly arranged.

The friction of the gearing only, in this case is 19·706 per cent., the friction of the engines and gearing together being 28 per cent. of the total load.

By a reference to the summary it will be seen that the best results will be found in the gearing engine No. 8, but that No. 5 Example in the same class, and No. 1 in the direct-acting engines run it very closely.

The average percentages of the examples given show less actual work than I had expected to find, and I shall be pleased if any of the members will supply me accurate data or permission to indicate other examples for the purpose of revising this paper and making it more complete.

In conclusion I would say that the lessons to be learnt from carefully studying the examples are briefly as follows:—

That spur gearing engines give the best result when not complicated with rope driving.

That rope driving engines show the best results at high rope speeds, and that direct driving from the main drum is very desirable.

That belt driving engines for developing large powers are only equal to the average rope driving engine, with fewer advantages in other respects.

That the direct-acting type of engine is likely to be very efficient.

DISCUSSION.

Mr. JOSEPH NASMITH remarked that, in the first place, the paper was practically emphasising the remarks which were made in the recent discussion on the comparative merits of different methods of main driving. At that time, it was laid down by Mr. Rea, that wheel driving was unmistakably the most economical in relation to friction. In regard to this point, he might say that to put down the loss from friction by well-constructed gearing at from 5 to 7½% was, at any rate, shown to be erroneous by the indications taken by Mr. Saxon. It was perfectly certain that no concern, working under ordinary conditions, worked with a friction diagram of 5 to 7½%, but of the fact that geared mills were unmistakably the cheapest in this respect, he thought, after the results indicated in Mr. Saxon's paper there could be little doubt. After receiving the advance copy of the paper he thought he would try and analyse the summary in a more extensive fashion than that of the author, but before referring to it he would like to mention a few points. On page 170 the methods of judging economy were referred to, and it was stated that "the commonest was the number of lbs. of coal per indicated horse power per hour, another test being that of the weight of steam used." Undoubtedly these were two excellent tests, but from the point of view of the man who paid for the coal the best method was to take it in pence per horse power per hour, because everyone was aware that there might be a cheap or a dear coal used, and therefore, the question resolved itself, which was the cheapest? He believed that if the trouble were taken to run the cost out into fractions of pence per horse power per hour, it would give a more accurately commercial comparison than the methods mentioned by the author. If now they analysed the examples given it would be seen that in the case of the wheel-geared mills the loss by friction was 24·76 per cent. of the total load. When the power was first transmitted by spur gearing,

but subsequently within the mill by ropes, the loss was 27·77 per cent., while when all ropes were used the friction increased the loss to 28·6 per cent. If the comparison made was one dealing with wheel gear only, then they found the mean loss by friction was 212·26 horse power, while with ropes the loss was 279·56 horse power. In other words 67·26 horse power more was absorbed in transmitting the power by ropes than by wheels. This at 2lb. of coal per horse power per hour, with coal at 7s. per ton, was equal to a weekly loss of £1 3s. 6d. Another factor worthy of note was that, if the comparison be confined to the engines giving off from 900 horse power upwards, the average loss in the case of wheel gear was 244·5 horse power, while in the case of rope gear it was 320·66 horse power, giving a mean advantage in favour of wheels of 76·16 horse power. These figures only confirmed the experience previously gained that so far as the *friction* loss was concerned the most economical results were obtained when wheels were employed to transmit the power. Of course this was only one aspect of the subject, and there were many others which had a considerable bearing on the question as to the best system to adopt.

He thought these tables and this method of analysis showed conclusively that when there were ropes used power was always lost. Of course there were many other points to be taken into consideration before the advisability of adopting ropes or gearing could be decided, but on the matter of friction he did not think anyone could show that the bias was not absolutely in favour of gear driving. If it were enquired how it was that so much power was lost, there were an infinite number of cases to indicate that it might arise from several causes such as the arrangement or spacing of the bearings, or in the positions of the bearings relatively to the pulleys from which the power was absorbed. There was, undoubtedly, a great loss of power, and for that reason he was under the impression that the assumption made in one of the examples by the author, "that if the power had been increased the friction would be a much less per centage," was hardly warranted by the facts of the case. The chances were that when the extra power was put on, so many more machines would be added, and the friction diagram would probably have been increased.

He recently received notes of a case in which a pair of engines of good construction were giving off 125 horse power, and there was a difficulty in keeping up the steam. In making an examination, the fault was found not in the main driving or second motion shafts, but in the line shafts, which were found, owing to carelessness, to have fallen each out of line, and the rigid bearings which were adopted caused a great loss of power. By adjusting this defect an immediate saving of 15 horse power accrued.

The necessity of carefully putting on a belt was not always looked upon as of paramount importance, and in many textile factories the straps were stretched to compensate for the short distances between the centre of the shafts. If the fact could be impressed upon those concerned that when a strap was stretched too tight it caused an excessive and harmful pull on the bearings, they would be doing a useful work to society, and much power hitherto wasted would be saved.

In the course of his paper the author came to the conclusion that rope driving showed the best results at high speeds, and the examples he furnished bore out that deduction, but, behind that there was another question which ought to be considered if ropes were driven at the highest possible speeds. It might be of advantage where the load was settled once and for all and it was not going to be increased, but if the load might be added to, and there was a chance of more power being required, then he contended that by running the ropes at their highest working speed the reserve of power was being taken away, and the full advantage was not being had of this system of rope driving, which should be obtained. One of the great advantages of rope driving over gear driving was the facility for increasing speeds in order to gain a little extra power, which was impossible with wheel driving when running over a certain peripheral speed. Therefore, this system of rope driving did possess, in spite of its loss by friction, unmistakable advantage for the mill owner. Further, the loss of power which arose from too high a centrifugal speed of ropes was not without some bearing on the matter, and this factor rendered it desirable to get ropes as light as possible, consistent with the necessary strength.

Mr. JOHN TAYLOR briefly complimented the author on the admirable manner in which he had brought such a practical subject before the Association. The main point in the paper, to his mind, was in the summary, in the column of average friction percentages. He might say that it was his privilege at one time, to be connected with a firm who took a more than ordinary interest in endeavouring to ascertain the accurate power developed in their engines, the friction and the power required in different branches of their mills (say in the spinning mill), the actual power required in the blowing room, the carding and the spinning rooms. In taking a friction diagram they might be easily led astray, as, for instance, in a cotton mill the carders frequently left the belt on the fast pulley. This was done in order that they might get the highest production possible. He generally took repeated diagrams, and based his conclusions on an average comparison of them. They had one mill in which were a pair of single-acting condensing beam engines, 40in. cylinders, 7ft. stroke, 30 revolutions per minute, 65lbs. boiler pressure, indicating 700 horse power: the actual friction diagram from engine and gear alone only amounted to 15 to 18%, which was repeatedly verified.

In a second mill, in which were a pair of single-acting beam engines, 31in. cylinder, 5ft. 6in. stroke, 40 revolutions, 350 horse power, they obtained an average friction diagram of about 12 to 14%. In looking through the author's paper he could not account for the increase in friction, say from 15% to 25%. It might be accounted for by the multiplication of cylinders and tight fitting pistons. He might, in conclusion, remark that in rope pulley driving there was not the same oscillation as a shaft driven by gearing; the consequence was that it got into a dead position, and if it was not provided with positive lubrication, trouble ensued. The same applied to belt driving, because it was in one position unless there was a change of power.

As a rule, in his opinion, the friction arising from belts or ropes was greater than from gearing.

Mr. E. G. CONSTANTINE said that if Mr. Taylor had sufficient data for the purpose it would probably be useful to the members

if he would amplify the particulars of the examples of friction which he quoted. He was of opinion that if those members who were most conversant with and who were frequently taking friction diagrams would send their results to the council they might be tabulated for the general use of the Association.

In response to Mr. Constantine's remarks, Mr. Taylor wrote as follows: I have looked through my old indicator books but am unable to find the friction diagrams referred to. I am certain, however, that my statement is correct. The difference in the two cases is accounted for in the length of time the two plants had been at work. The engines and gearing of the plant giving 12% to 14% were erected in 1855. The shafting plant for 1,000 spindles would be 30% lighter than in the other case of 15% to 18% friction. Besides, everything worked well up to its bearing – an important point in considering these matters.

Single line friction diagrams are not reliable, which would be amply proved if the indicator is left at work say twelve or fifteen strokes; the variations are then shown clearly. I do not attach much importance to the question of boiler pressure when friction diagrams are taken, because everything has to be subjected to giving a normal speed, which should be attained and maintained, say for a quarter of a minute, before starting the indicator, the result so obtained being the most reliable.

Mr. A. G. Brown said he greatly appreciated the author's paper, but at the same time he would like to have heard more information *re* the methods by which the figures and conclusions were arrived at in the paper. Mr. Taylor, he thought, touched upon an important point, namely, the difficulty of obtaining accurate results in friction diagrams; although the engines would probably run steady enough with a fair load, it was very rare that they would do so when light. In the paper, unfortunately, the friction of the engine was included with the friction of the gearing, which complicated matters.

On pages 172-3 the author gave two examples of the friction of engines alone; in one case the engine was speeded at 50 revolutions, or about 11 per cent. above the speed at which it ran with the load of the shafting and gearing on, so that the friction then

should not be taken as being the same as when running at the slower speed with the gearing on. And if they reduced the percentage of friction mentioned, to correspond with the reduction in speed, the friction of the engine would be something like 5 per cent. of the total load, which he thought could not be the case. Another example of friction of engine alone gave just double the per cent. mentioned above, which was rather high for large engines and very good for small ones. Mr. Taylor mentioned a case of friction of engine and gearing equalling 15¼ per cent. of total power, which was lower than he had ever come across, although it might be possible with little and extremely good gearing. Without in any way questioning the intention to state accurate figures, he thought the results given in the paper were so varied that it would be difficult to draw correct conclusions from them. In the case of the spur gearing, there were but three examples which were mentioned in the paper as being all gearing, the remainder being mixed up with other methods of driving, and which, of course, materially altered the results. Also the percentage of friction of the engine in one case might easily be double the per cent. in another, so that there could be no clear deductions made. Then these ten examples of gearing, (in whole or in part), were averaged and compared with two examples of another method of driving, which he did not think a fair comparison. Referring to example 7 of rope driving, in the summary, it must be admitted that it was a large engine for the power taken off, *i.e.*, 393 indicated horse power, and the ropes were equal to over 700 horse power, which it could readily be seen might greatly increase the friction. He had not had time to analyse the examples, but he thought if they were again gone through in this way, it would be found that there were reasons for the diagrams showing greater friction in some cases than in others, not at all connected with the system of driving; in any case he was of opinion that unless a large number of diagrams were taken and averaged, or continuous diagrams on the recorder taken, accurate results would not be obtained. He ventured to express the opinion that the results tabulated by the author had been taken from too few diagrams, and nearly all were complicated with the

friction of the engines and with several methods of driving in the same mill. In rope driving, as remarked by Mr. Taylor, it was easy to increase the friction by putting the ropes on too tight. The author, in some cases, had indicated that the rope driving was "new," which he supposed was merely a comparative term; if they really were new the result should not be considered at all. As regards the direct-acting engines, it would enhance the value of the paper, if the author would try and obtain some friction diagrams in order to obtain a further comparison. In these cases there should be but little difficulty in disconnecting the engine. He might add in conclusion that he had always been strongly in favour of gearing as compared with any other methods of driving, but he did not think the paper proved its advantage.

The President (Mr. G. B. Goodfellow) said that the thanks of the members were due to Mr. Saxon for having brought such an interesting subject before them that evening. He thought, however, along with other speakers, that the author had not obtained some of the best results. He was rather sorry that the examples were in many cases composed of mixed methods of driving, because, as many of them were aware, when ropes were adopted as secondary driving after wheels, the loss of power was very much increased. He was under the impression, however, that Mr. Brown was rather hard upon the author, though probably he did not really intend to question the accuracy of the figures in the table. Judging from his own experience he did not really question them, because many, in fact most, of them were aware how exceedingly difficult it was to obtain such information, even in instances where the engines were constructed by the experimenter. It was, therefore, much more difficult to obtain similar information from other makers or firms where other engineers were employed.

The author appeared to have missed one point, which was somewhat difficult to state in the particulars given; if the average of the spur gear were taken, that was, the average pressure of the low pressure cylinder, it would be seen that the average pressure was less in the rope driving engines than in the spur geared engines. Say, if the rope driving engines were

loaded to the same ratio as the spur geared engines, there would be apparently less loss of friction, because an engine when made for a certain power had a certain number of ropes placed upon it to do a maximum amount of power, therefore the whole of the ropes were applied to the smaller power. The differences between the rope gear and the spur gear were not so great as he had expected to find them. He must confess that no one more than himself could be more partial to good gearing, though at the same time he recognised the nearly absolute necessity of applying ropes to most of the modern driving, especially where large powers were concerned.

Mr. Nasmith had referred to the advisability of running ropes at high speeds, and of course that was one of the advantages of rope driving. There must be small ropes and large pulleys, which latter necessarily meant high speeds. A great deal of the loss of power in rope driving, he maintained, was due to the bending and straightening of the ropes.

Mr. Nasmith remarked that it was inadvisable to run a rope near its limit because an increased speed could not then be put upon it, but he (the President) thought such a fact applied to all classes of machinery, and not only in main driving of wheels, ropes or pulleys. For the sake of economy they got the most out of a machine that could be obtained.

It would be seen from the rope driving examples that those with the highest speeds were, generally speaking, the best. He was quite prepared to maintain that a new modern spinning mill of 1,000 horse power could be fit up at as little cost and at as little loss from friction with rope driving as with spur gearing. As he mentioned before, wheel gearing he admired, but at the same time it was good to-day and bad to-morrow, on account of the difficulty of keeping it well up to its work. He concurred with the author in the remark "that the arrangement, construction and lubrication of the gearing was the principal defect," which he could amply prove from instances of his own experience.

Referring back to the friction of engines, he might say that during a number of years he had had opportunities of running engines alone, without any gearing, and he did not think that

the figures quoted by the author would be greatly altered, even if he collected more data. Friction diagrams were difficult to obtain at any time, but he was of opinion that the author's conclusions were sufficiently correct to base any ideas as to what might be required for future work.

The author maintained that spur gearing gave the best results, but it must be borne in mind that so long as mills were built where 1,000 horse power and upwards had to be put in three or four rooms, it was difficult to get gearing to stand it.

As regards belt-driving engines, he must confess that he did not like them, and especially for one reason, that it was difficult to divide the power amongst a number of shafts.

With respect to direct-action driving, he thought it was more useful in small cases than in large ones, and it was hardly applicable to the generality of Lancashire engineering. And even for electric-lighting purposes it was not always advantageous. Where there were rigid engines running at high speeds a great many difficulties arose which more than outweighed the small saving gained in the less friction.

The President concluded by moving a vote of thanks to the author for his interesting paper.

The motion was carried with acclamation.

Mr. Saxon, after briefly expressing his appreciation of the vote of thanks which had been accorded to him, replied to the various remarks made in the discussion.

Referring to Mr. Nasmith's remarks, he said, that generally speaking they confirmed the statements and conclusions given in the paper.

The analysis he gave was correct, but might with advantage have been put in tabulated form, showing the actual loss and per centage collaterally, as indicated below.

Tables showing difference in total loads of an engine of spur gearing and an engine of rope driving based on the averages given in the summary, for the same actual load given off:—

Taking actual figures as given in the Paper.

	Average full load of six examples of gearing and eight examples of rope driving in indicated horse power.	Average friction in same examples in indicated horse power.	Average actual load in same examples in indicated horse power.	Average per cent. of friction in same examples per cent.	Average per cent. of full load in same examples per cent.
Gearing	902·976	212·3	690·676	23·5	76·6
Rope Driving	978·13	279·56	698·13	28·5	71·5
Assuming an actual load of 700 indicated horse power from an engine of each type and making the indicated horse power proportionate to the above, then,					
Gearing	915·6	215·16	700	23·5	76·5
Rope Driving	980·3	280·3	700	28·5	76·5

The difference in the full load indicated horse power, in two engines giving the same actual load of 700 indicated horse power is 980·8 equals 65·14 indicated horse power, more required in an engine with rope driving than with gearing.

The above table showed almost the same result as Mr. Nasmiths' calculations, but that fact was purely accidental, as his analysis of the cases given was made quite irrespective of the size and power of the engine of each class. With reference to the assumption which Mr. Nasmith said was made by the author in one of the examples, viz., "that if the power had been increased the friction would be a much less per centage," the author would point out that the engine maker wrote him, asking this explanation to be made, and the statement may be taken as being fairly correct.

With regard to gearing being out of line and absorbing much additional power, this evinced the necessity of gearing being well arranged and well looked after by competent persons, as the gearing in a mill showed considerably more frictional loss than the engine.

Mr. John Taylor's remarks were not supported by any evidence stronger than his memory, and as the cases cited by him were taken several years ago, they could not be considered to bear a fair comparison with the cases referred to in the paper, which were all up to date.

If friction had increased in engines, and there was not sufficient evidence of engine friction alone to make the comparison, it was comparitively slight, even with the tight fitting pistons, and extra cylinders, as in the worst case of engine friction, which indication was made within one hour from the engine being first started, it was only 10·8 per cent., giving an efficiency of 89·7 per cent. through the crank shaft. The author would be disposed to attribute the increase in friction, mainly to the speeding up of the shafting throughout the mills, and the addition of countershafts, which had taken place during the last few years.

Mr. A. G. Brown would no doubt rather have had the time of the meeting occupied with explaining methods than results. Every engineer was acquainted with the difficulties accompanied with taking friction diagrams.

In each case there were several indications made and the mean result was taken. As the diagrams were either taken personally or by competent persons, the author had no doubt as to their accuracy. Mr. H. Hodgson had also explained the method he had adopted in indicating the engines which were referred to as "examples of friction of engines only," and could also vouch for their accuracy. With reference to Mr. Brown's remarks as to some of the examples given as spur-geared engines, and having some counter rope driving included, the author would point out that there was scarcely a mill working, in which there was not a certain amount of rope driving, either from the line shafts or counter shafts, even when the main driving was by wheel; and he only referred to those cases of spur geared engines where a considerable amount of the power was taken from the second motion shaft by ropes.

The proportion of power taken off was very small in those cases where rope driving was used in the rooms of the mill from shaft to shaft.

Considering the number of examples obtained, and the difficulty the author experienced in getting millowners to allow their engines to be run without load for a sufficient length of time to obtain friction diagrams, the results furnished might be taken as reliable, notwithstanding the reflections of doubt, expressed by Mr. Brown.

The term "new" as applied in the "Descriptions of Engines and Gearing" refers to those constructed during the last five years.

In reply to Mr. Goodfellow's remarks as to some of the best examples and results having been omitted in the paper which he thought might have been procured, the author may say that it would have been a difficult matter to have got the best results merely, and the author's original intention was to get the best results of the respective classes of engines made by the leading Lancashire engineering firms, but as pointed out, however, in the opening remarks in the paper, several firms were prejudiced enough to refuse the desired information.

Mr. Goodfellow's reference about the average pressure and the load being less in the rope driving engines than in the spur gearing engines, was in order, but it did not in the least alter the general conclusions arrived at by the author.

As regards the other remarks of the president, speaking generally, the author concurred with them.

ECONOMIC POSSIBILITIES OF THE GENERATION OF ELECTRO-MOTIVE FORCE IN THE COAL FIELDS AND ITS APPLICATION TO INDUSTRIAL CENTRES.

READ SATURDAY, 12TH NOVEMBER, 1892,

BY

Mr. B. H. THWAITE, C.E.,

LIVERPOOL.

The recent history of the useful development of the application of electric energy, reads like some marvellous story, emanating from the brain of an Oriental dreamer.

An engineer loving his noble art, has only to look into this history with thoughtful interest, to be drawn into the train of constantly increasing length, of those, who follow and proudly own allegiance to, this fair godess Electra.

After all, the employment of electric energy for the uses of man, is only another instance of the wisdom of imitating the economic ways of Nature.

The entire organic system, whether plant or animal, is controlled and reared by this magic and mysterious force, that, like the initiation of Life, can neither be understood nor described.

The sensible impressions of life and the movement of the muscles are merely the result of this electric energy, produced by the chemical actions set up by the introduction of nitrogenous and carbonaceous food elements into a solution of the gastric juice of the human system. The spinal column is the transformer, the brain is the switchboard, and the nerves the conductors to the distributed motor elements of the anatomical system.

The modern development of applied Electrical Science is extending these vital methods of dynamic effort to the external areas around man, by which, in the instance of, in one example, the nervous impulses moving his tongue, are trans-

mitted miles away to be imparted by the telephonic apparatus to the tympanum or drum of the ear of another and listening man. The brain impulses, or thoughts enclosed in speech, are thus transmitted beyond one's self in Nature's ways, so that here we have the natural electric impulses lengthened by the skill of man to an almost indefinite extent, and adding to the convenience and resources of humanity in its fight for existence.

The force created by the energy of man is also transmitted to far-off distances, and now we have our country becoming gradually converted into a semblance of the human nervous system, a semblance that, as time flies on, will become greater and greater.

What could be more appropriate than the location of the electric energy producing elements, in positions appropriate for the acquirement of the highest efficiency and economy, and in its transmission to civilized industrial centres, where the impulses of nervous energy direct and control the operations of supply and demand, of the requirements for sustaining life and the comforts associated with it.

The onward rush of this marvellous electric energy has drawn by its power of attraction most of the workers in the field of applied science, but the field of operation is so expansive and so allied to the engineering art that no engineer should draw back from the attractive embrace of this mysterious force.

Unlike the evolution of the use of steam, and the conception of the steam engine, which was practically developed by the genius of one inventive mind—that of James Watt—the minds of most of the intelligent physicists and mechanicians of all civilized nations on each side of the Atlantic have been concentrated in the work of advancing the application and widening the field of use of this fascinating form of energy.

Manchester, the cradle of many of the great engineering developments, has through Joule and Wilde contributed her quota to this laudable effort, and to-day it may be truthfully asserted that no other practical or applied science has had, measured in terms of time, an equivalent success to that of the application of the science of electricity and its uses, and the resulting sum of the intelligence of the workmen in this field of

science is the greatest proof we have of the broadly advancing intellect of humanity.

No other applied science has by time measurement received the same degree of mathematical treatment. Whether the progress of practical development has been benefitted by this associated analytic treatment (and its deducing value possible by this mathematical analysis) may be an open question. Mathematicians are generally more of analysts than synthesists. They rarely conceive or create, although in Lord Kelvin we have a brilliant exception, but this may only prove the rule.

It has been asserted that no real progress was made in the development of electro-generating machines until the line of progress indicated by purely mathematical reasoning had been ignored. Be this as it may, it can be proudly stated that the present elements constituting the electric generator—*i.e.*, the apparati for raising and lowering the pressure of the electric energy to be distributed—its distribution and final employment at pressures of controllable limits, in an inverted or reversible type of electric machine, have been raised to an almost maximum possible degree of efficiency, at least eight times higher than the best of the high-class steam engines now constructed.

Divested of mathematical treatment, the active and essential principles underlying and controlling technical electro-dynamics, can be mastered by any ordinarily intelligent engineer, to whose craft in a great measure will fall the future care and control of this mysterious electric force.

These remarks are prompted by a desire to direct the eyes of all engineers to the importance of studying and mastering the main principles underlying the construction and application of electric generators and the intra elements between it and the motor. They will find a fascinating field open before them, in which every one may discover a furrow in which to plough for his own advantage and for the benefit of an expanding electro-technical science.

Switzerland, thanks to her natural waterfall resources of the Alpine areas, is rapidly becoming an industrial centre of an importance, diversity, and magnitude far away beyond the dreams of the most ardent Swiss patriots. And this cheap and convenient power is inviting, with effect, the opening up by not

only the Swiss republican citizens, but by strangers, of new and important industries, and to-day Switzerland may be said to annually produce the largest weight of aluminium of any country in the world.

Our own carbonaceous fuel power resources have been one, if not the main, source of England's industrial greatness; but with the entrance of this new electric agent into the domain of practical engineering, the advantage we owe to our contiguity to the coal fields and to our possession of these fuel supply areas is being gradually undermined, and unless we utilise these resources so as to obtain the maximum practicable recovery efficiency from them by the aid and assistance of this wonderful electric agent, our industrial career will have another and serious retrogression.

Our coal fields have advantages that neither falling torrents of water, high tidal ranges, nor yet the force of wind currents possess. The supply of energy is constant, and does not depend upon the temperature of the one nor the barometric pressure and lunar dependence of the other.

Advantages of a Central Power Generating Station, or the Distribution of the Power from a Central Source.

The arguments that may be pertinently advanced in favour of a Central Power Generating Station are almost identical with those associated with the centralisation of a gas and water supply, or a sewage treatment station, but the arguments are more adequate than those in favour of either of these examples.

Assuming for a moment that the textile and other factories and workshops were all connected up with the power transmission mains conveying power generated at some large centralised power-generating station. The factory owner would not then have the anxiety and responsibility of his power plant, involving the care of the skilled and unskilled labour element. The space absorbed by the steam boilers and economisers, engine house, coal stores, and chimney would not be required, and in towns this consideration might not be of unimportance. Then the troubles of coal and suitable water supply, and all the attendant requirements involved in the proper care and supervision of a steam engine plant would

be avoided. The boiler insurance question would not trouble him. He would, in respect to his motive power supply, be as free from care as the proverbial Jolly Miller, whose power came from the winds of heaven or from the falls of rivulet and stream.

The waste of fuel in early lighting and during meal hours would be avoided, and the excess of labour almost always associated with the conditions of isolated and comparatively small steam power plants would be saved.

At the exact hour in the morning the mere movement of a switch throws the plant into operation, and at night the quick turn of a switch handle cuts off the power.

The interest on the cost of the transmitting gear, the steam engine, the steam boilers, and the buildings during 14 hours out of the 24, which is at present lost, would, by the supply of power from a central generating station, be avoided.

The same main service, with the addition to the electro-motor of a transformer, would be available for lighting purposes, for elevating goods and traversing them, and for ventilating, fire extinction, electrolytic and innumerable other purposes.

In the event of a decision to stop the factory for an indefinite period, there is no expensive staff to maintain the plant in a condition of efficiency,

In deciding to stop the works or to disestablish them, the serious question always facing the owner of a steam-engine and boiler plant—"of what shall I do with it"—is met by his simple request to the staff at the Central Generating Station to remove the electro-motive power plant. This can be done without much trouble, and with little depreciation in the value of the machines. Whereas, who would lightly face the removal of a large steam-engine, steam boiler, and economiser plant? *not* to mention the abandonment of the chimney and buildings.

We all know the number of steam-engine and boiler plants lying and rusting away at various abandoned or unlet works throughout the country, each plant having in its time the possibilities of useful work.

The reduction of skilled labour required in proportion to the power produced, that would follow the establishment of a Coal field Central Generating Station, would be very great; in fact, this feature alone justifies the correctness of the principle on

economic grounds, of the establishment of large Central Power Generating Stations.

Another feature is the fact that an additional extension, involving extra power plant, can easily be accomplished, whereas we all know how difficult in many instances it is, to add extra steam-power plant, simply owing to the exigencies of space and position.

The compactness of the Electric Generator Machinery permits it to be placed in positions absolutely prohibitive for any other kind of Power Generating Plant.

Besides these advantages, there would be no troublesome factory chimney belching forth its smoke to poison the atmosphere and defeat the beneficent natural laws involved in the cycle of the conservation of energy.

Thanks to the Commission appointed some years back by the Birmingham Corporation to report upon the compressed air project, we are able to look through the mirror of defects of the existing system of power production, and can crystallise in a few sentences their more important disadvantages.

The Commission—the only relic of that ill-fated scheme—did their duty thoroughly, testing a great number of engines in every-day work, and varying in power from 4 to 25 nominal h.p. The total fuel consumption was ascertained, as well as incidental or associated costs.

Owing to the extremely intermittent and varying character of duty, the engines working under the most favourable conditions only averaged throughout the day one-third of their working capacity, but under the worst conditions only one-seventh of the maximum capacity was utilised.

The coal consumption in the most favoured examples was 8·5 lbs. per I.H.P. per hour upon the average daily H.P., and in the worst example the coal consumption attained the phenomenal one of 86lbs. per I.H.P. per hour.

The Commission carefully state, that these results are not due to the imperfect construction of the engines, but are consequent on the varying character of the work required, and the *necessity* imposed upon each power user of maintaining a plant and steam engine equal to his maximum requirements.

His motive power must be at hand and be available often at a moment's demand, and in the interim, steam is blowing from, and fuel is wasting at, his boiler.

The following advantages were accepted as belonging to any economic and effective method of distributing power to small users, and available for direct application to isolated machines: No heavy and costly foundation; no expensive shafting required; no smoke nuisance; no ashes or removal by cartage; cost of water and coal avoided; no danger from explosion; full power at any moment; only to pay for power in proportion to amount used. A municipal advantage would be the lessened coal traffic through the streets, and waste of the fuel *en route*.

As an illustration of the advantage of central supply plants in lieu of isolated ones, and which will be still further emphasized, let us refer to one example.

If there are 10 engines, each of 10 H.P., and each engine is required to work only one hour during a day of 10 hours, under the present system at least 100 H.P. of steam producing plant would be necessary, whereas with a central power generating station connected with each works, it is quite possible where the working hours are sufficiently distinct to adequately permit of an engine power equal to 20 H.P. to supply the wants of the 10 power consumers.

The first consideration is to convert the thermic value potential into dynamic energy, and with as high a degree of efficiency as possible.

We know in precise terms the degree of thermic energy possessed by the fuel; we know also, that besides this thermic capital, the fuel contains a nitrogenous constituent which it is our bounden duty to restore to the plant life from which it originally emanated, and this same duty should compel us to return the carbon of the fuel to the plant in an assimilable form as carbon-dioxide and the hydrogen as H_2O or water.

Is it possible to define what is the most economic and practically ideal method of converting heat into work with the assemblage of mechanical parts at present available from actual working data? An answer in the affirmative may be given. The inevitable conclusion of everyone who examines the subject without bias, will be, that the procedure that will give this ideal

method to fulfil the highest practical standard of efficiency and satisfy the exigencies of duty is as follows:—

1st. The conversion of the solid fuel into a gaseous condition.

2nd. The abstraction of the nitrogenous value from the fuel, and its conversion into a condition suitable for agricultural fertilization.

3rd. The direct combustion of such gaseous fuel in the combustion cylinder of a gas motor, for the conversion of the thermic into dynamic energy.

4th. The transformation or transmutation of this dynamic into electric energy, or into electro-motive force.

The graphic diagram Plate 1 and 2 shews with approximate accuracy the apportionment of the thermic capital supplied by a gas or a steam engine and its allocation for useful, effective work, and the loss by unavoidable dispersion by conduction, sensible heat, and as unexpended thermo-chemical assets in the waste gases.

The ultimate possible results of a fuel gas and gas motor plant on a large scale is, that with such a plant, the dynamic power enclosed in the indicated card of pressure of a cylinder will be equivalent to the raising or elevation of 33,000lbs. one foot high in one minute may be obtained with an expenditure of from $\frac{5}{8}$ to 1 lb. of solid fuel.

That the fertilising value from this fuel should be equivalent to the supply per ton of fuel of the equivalent of the nitrogen to that contained in 22 to 28 or more pounds of ammonia-sulphate. See diagram, Plate 3, of ideal plant.

At present these conditions cannot be economically obtained from any other form of motor generating procedure or plant than a gas-engine.

The procedure of the steam-engine method has an associated loss far greater than the gas-engine, and although it is possible to convert the fuel into a gaseous condition and recover the nitrogen, there are losses attending the employment of such a procedure that partly neutralize the gain.

It must be obvious to anyone that direct and perfect combustion actually inside the walls of a motor cylinder must be more economic than the combustion more or less imperfect in the

flues of a steam boiler, even if effected under the most favourable conditions.

Besides the fundamental advantages of the gas plant and gas motor procedure, the instrument itself is more effective in its useful disposal of work represented by the indicated energy. Take the indicated energy of both the gas and the steam motor and compare it with that available for external work; it will be found that the former is very much more efficient. The thermo-dynamic efficiencies of the two types of motors in percentages of the theoretic maximum are shown in Plates 2, 3 and 4.

It is well known that with the type of steam engine utilised on our Ocean Liners and for driving our Largest Mills, the reduction in expenditure of fuel for a given dynamic output and value is very considerable, and the reduction clearly shown in the diagram, Plate 5, is a striking and eloquent witness in favour of large power steam engines, which are only available for Centralised Power Stations.

But for generating power for driving electric generating machines we require still higher efficiencies, and with relatively smaller powers. A motor of 500 H.P. is the largest that should be used for this character of work. The efficiencies of Dynamos or Electric Generating Machines are so nearly perfect that there is only questionable advantage in building excessively large types; but the motive power and elements should be such, that if one or two parts go wrong, it will not involve the arrestation of the entire motive power plant; besides, it should be possible to reduce or increase the power of dynamic energy production in proportion to the demand, and with large steam engines of 1000 H.P. and upwards this would not be practicable.

There is another and important advantage in relatively smaller power gas engines—the pulsations of piston effort could be so arranged that their effect on the supply would be inappreciable.

In the arrangement of the plant (see Plate 6) for the projected Coal Field Generating Stations, gas motors of 300 B.H.P. (see Plate 7) are intended to be used, a pair of these engines being allotted to each alternating current machine, coupled direct, one engine driving the armature in one direction, and the other the field magnets in a contrary direction.

CHRONOLOGIC TABLE

Shewing the Genesis and Historic Phases in the Development of Electric Transmission of Dynamic Energy.

Date.		Discoverer.
1826..	Conception of the idea that when an armature was forcibly removed from a permanent magnet, the force expended in this removal set up a current in wire surrounding the armature	MICHAEL FARADAY.
1865..	The direction of the current produced by the severance of an armature from its poles to a wire surrounding the poles, the result being an increased inductive action and increased induced current, the intensity accumulating until the saturation point of the bar of iron forming the magnets is reached	VARLEY and WERNER SIEMENS
1867..	The use of electro magnets excited by the current from a separate electric generator machine in lieu of the steel magnet	WILDE (Manchester).
1873..	Accidental discovery of the reversibility of the electric generating machine, at the Vienna Exhibition.	
	NOTE.—It appears the Gramme Company had two dynamos on view, and intended for lighting purposes. One of these machines was in motion, the other idle; a workman seeing some electric cables trailing on the ground, and thinking they belonged to the second machine, connected the cables up to the terminals of the machine that was idle. To his surprise the armature of this machine commenced to revolve	Accidental.
1891..	The Triphasic Alternating Current System (high pressure) applied by the Allgemeine Elektricitäts, and Gessellschaft, and Maschinen Fabriken Oerlikon for conveying power (over 100 h.p.) from Lauffen to Frankfort, a distance of some 112 miles, with a loss varying from 30 per cent.—See graphic diagrams, Plates 9 and 10 for wet and fine days. This is the most triumphant success hitherto recorded in the transmission of power over long distances. Fuller details are given in the table of power transmission *vide* appendix.	
	N.B.—The Triphasic Alternating system, known as the Drehstrom, consists in the use of three wires, each having its corresponding alternating current; the phases or impulses follow each other. See diagram of magnetic fields, Plate 11.	

OUR NATURAL SOURCES OF POWER.

In the face of new industrial competitors, who owe their competing origin to the energy of falling water and its electric possibilities of transmission, it is worth while to enquire whether or not we have natural power resources as auxiliaries to our coal fields.

The author had reason a short time back to make a careful examination of the hydrographic data available, and from this he has prepared the diagram which shews at a glance the minimum tidal flow of the British ports having a range of possible use. The author entered very carefully into the question of whether it was economically possible to provide Weston-Super-Mare, having a high tidal range, with power by means of turbines placed in the impounding walls enclosing water at high tide, the high tide water flowing through turbined shafts to the low tide level; but on examination of the probable cost of retaining walls, turbine, and turbine shafts, he found that it would be less costly to erect a central power generating station on the opposite Welsh coast, and convey the energy by submarine cable laid across the Bristol Channel.

Of course, if ever the time arrives that our coal resources fail us, the range of tidal flow in the towns indicated on the diagrams, Plate 8, may become useful.

The wind power in inaccessible positions removed from fuel areas of supply may, by the employment of modern wind sail mills, be suitable for generating electro-motive force.

METHODS OF TRANSMITTING POWER.

The practicable methods of transmitting power may be divided into three—firstly, the hydraulic; secondly, the pneumatic; and thirdly, the electric. For ordinarily quick speed work hydraulic transmission of power is not very well suited. Air or pneumatic power transmission is economically applicable for short distance transmission of small power. In the pneumatic system for forwarding light parcels, as adopted at the General Post Office, London, and at Liverpool, pneumatic transmission has its happiest application; but for comparatively heavy work, and distances over two miles, the loss of efficiency is most serious. On the day of the discussion of Mr. Sturgeon's

paper, read at Liverpool in 1887, and describing the Birmingham Compressed Air Distributing Scheme, the author received a letter from Mr. Charles Brown stating that the Oerlikon Company had succeeded in transmitting several horse-power of energy electrically over a distance of some eight miles, with a loss of only some 25 %.

It must have occurred to those who understood the meaning of this information that such an economic result, spelt obsolete, applied to other rival methods of transmitting power, and especially to that of the pneumatic transmission; and further, that such a practical result meant the opening out of a vista to the eyes of engineers, the gaining width and length of which it would be impossible to calculate.

Since this first practical triumph, the Oerlikon Company have laid down a very great number of power transmission installations, but none more famous than that of the Lauffen-Frankfort project, which suddenly and vastly widened the vista of usefulness and effect of this magnificient triumph of man in the control of hidden mysteries of Nature's ways of work to the benefit of humanity.

The Lauffen-Frankfort results demonstrated, thanks to the initiation of Herr Von Doliro Dobrowolsky, that for distances of upwards of 100 miles the transmission of power can be accomplished with very little loss of the original potential energy (see Plates 9, 10 and 11), whilst its rival, the air compression method, has succumbed to practical exigencies, both in the instance of Birmingham and Paris.

The electric transmission of power is a solid success in practical everyday rough and ready use in very many instances, and in almost every part of the world, and is opening up new centres of industry, and new processes of production and manufacture, that could not have existed without the transcendant advantages associated with the use of this nervous-pulsating energy; no record of man's genius equals that on which are set forth—the history of the mastery of this natural means of transmitting energy for the purposes of sustaining and embellishing life.

The high tension or pressure system of transmitting energy has long been the acknowledged explanation of the high

efficiency of luminous condensation, or concentration in long distance planetory telescopy; and there is little doubt that when we obtain the right insulation, the voltage or pressure, that the pressure in electric transmission, will be increased to such an extent as to enable a very light wire to carry enormous potentials of energy with very little and even negligable losses of force due to ohmic resistance.

COST OF ENERGY TO THE CONSUMER.

Taking the report of the Birmingham Compressed Air Commission as a basis of computation, it appears that the majority of motive power plants did not exceed 20-H.P., and for all powers below this the cost may be taken to vary in the Metropolis between £10 and £18 per annum per horse-power. This amount covers the cost and depreciation of the engine and boiler, cost in repairs and lubrication, rent of land and buildings, insurance, coals, water, and labour.

The cost of this energy delivered electrically, and including the hiring rates for motor transmitter, should not exceed £4 10s. to £5 for 3,000 working hours per annum; it is most probable that the figures will be less, so that if the charge for energy was made to cost the consumer from £7 to £9 per horse-power per annum, it would be a great gain to him, not to mention the lessened anxiety, and he could also arrange to pay for his power in proportion to the amount used.

According to a letter from M. Emil Huber, of the Maschinen Fabrik Oerlikon, the price charged for energy varies from £7 2s. for powers above 10-H.P. and not exceeding 200-H.P., but for very small powers below 10-H.P. as much as £16 per horse-power per annum is charged to the consumer. See diagram, Plate 12.

ARTIFICIAL LIGHTING POWER DISTRIBUTION.

The author, in his report on the distribution of Fuel Power Gas, demonstrated † that, comparing the cost in value of heat units represented by a given volume of gas for the production of a specific luminous value, the glow incandescent lamp driven with a gas-engine (Otto cycle) *is 50% more efficient than a*

† On the Distribution of Fuel and Power Gas, by B. H. Thwaite (*Journal of Gas Lighting, Gas World, and American Manufacture, 1893.*)

bat's-wing gas burner; this is clearly shown by the graphic diagram. Of course, compared with the recuperative gas burner, the advantage is on the side of the gas.

If the price per B.T.U. is reduced to 3d. per unit, the financial advantage will then be entirely in favour of electric energy.

A glance at the comparative graphic diagrams, see Plate 13, which the author has drawn up from reliable data, shews clearly that as the cost of production approaches more nearly to that of the admirable Bradford Corporation electric lighting installation example, the reduction of cost of supply will be such as to permit the electric light to be not only the ideal and beautiful light of the fortunate few, but, that it will become the ideal and cheap light of the many.

The reports of the cost of transmission given in the appendix, shew that it will be possible to supply electro-motive force to the Metropolis at a price as to permit the Electric Light Supply Companies to distribute the light at such a reduction as will permit it to be economically used in comparison with gas, as ordinarily burnt with open flow bat's-wing burner.

Of course, it will be unreasonable to expect the Electric Light Companies to be able to reduce their price until the outlay in ways, trunks, and leads shall have become fully utilised; then, with a cheap source of energy, the reduction of cost will follow.

In two years, or sooner, the patent rights relating to the use of incandescent glow lamps will have expired, and this will alone reduce the cost of the lovely electric glow-light by at least 10%. Hence, if the electric energy is supplied from a great central coal-field generating station, and its pressure is reduced down to the required voltage of the different town supply companies, the electric light will soon find its way into the cottages of poor and rich alike.

THE METROPOLITAN AND GREATER LONDON LIGHTING COMPANIES.

Thanks to wildly reckless speculative and immatured projects, born of greed and inexperience, and the original legislative enactments relating to electric lighting, progress in London has been up to recent times practically crippled; but the lethargy resulting from early disappointments, has cleared away like mist before the sun (whose protegé the electric light surely is), and

to-day the Metropolitan companies in active operation, have already a capital of over three millions sterling, or one-fourth of that of the gas companies of Greater London.

Up to the last month, over 320 miles of service mains have been laid, and 90 miles of cables have been drawn in, and the plan of the Giant City shews that now the electric girdle practically embraces the main part of the Metropolis and is sufficient to supply some 360,000 lamps. One company, the London Electric Light Company, Limited, with a capital of £600,000, has already applications for 40,000 eight-candle power glow lamps, and 16,000 are already fitted, and it is estimated that the net revenue from the 40,000 lamps will alone be more than adequate to pay interest on the share capital. In Paris also, the recent development in the use of the electric light has been very striking and remarkable.

THE CHOICE OF THE MOTIVE POWER GENERATING SYSTEM.

One of the fundamental requirements in the choice of a motive power generating system, is a means of rapidly throwing off the total load of work without involving any waste or danger. Where the source of power is the natural waterfall, it is, of course, unimportant if the load is suddenly taken off, but with a steam-engine plant the sudden stoppage of the engines *throws the whole of the generated steam back on the boilers*, involving a sudden rise of steam pressure. Besides, the residual heat of the water and fuel is practically lost if the stoppage is for any length of time; and if the power demand is sudden, unless the steam-power is continuously kept up, this condition cannot be fulfilled. An ideal method of motive power generating system should permit the full power of the plant to be obtained in 10 minutes at the most. It should also be possible to suddenly throw the entire dynamic plant out of action without involving a serious strain on any part of the plant; and the whole time any part of the plant is in action it should be performing useful work.

Anyone who understands the characteristics of the two plants, steam and gas engines, will recognise that the only kind of plant available is the gas-engine one driven with its own cupola generator fuel gas.

There are other considerations in addition to those already mentioned that are of essential importance in deciding on the ideal system. The fuel power plant should be of such a character that as high a thermo-dynamic efficiency as practicable shall be obtained.

The author has prepared graphic diagrams see Plates 1, 2, 3, 4 and 12 to test the relative efficiencies of the gas and steam plant. The lesson they teach is clear and unmistakable. The economical dynamic fuel power for moderately large powers is the gas-engine.

A consideration of duty and economy compels one to insist, as a *sine qua non*, that for large powers, in which the consumption of fuel is high, the unvolatilizable hydro-carbons and the nitrogen associated with hydrogen shall be recovered. Of course, this involves the conversion of the fuel into a gaseous condition, and this desideratum can be obtained with either a steam-engine or a gas-engine; but it must be obvious to the veriest tyro in the science of thermo-dynamics, and it cannot be too often reiterated, that the gas thus produced should be burnt in the motor cylinder and the heat thus directly converted into motion in preference to burning the gas in a steam-boiler, which is only too often a monument of inefficiency.

In the event of misty fog suddenly rising, the whole of the gas-engine plant could be immediately started, because the storage of power gas in the gasholder can be established for any length of time without involving any appreciable heat loss or expenditure of labour, and can be utilised by simply the turning of a valve. When any portion of the load is thrown off, an equivalent power gas-engine is instantly stopped, and the gas energy flows into the holder until required.

The author suggests the displacement, for large installations, of storage batteries, by gas holders, for the storage of a convertible form of energy, available for use at a moment's notice, and involving no loss of energy by storage, for however long a time.

Therefore it may be accepted as an axiom, that the ideal fuel power dynamic plant, is the internal combustion engine driven with fuel gas stored in a holder, and from which the nitrogenous and other chemical assets have been recovered,

The author and Mr. Swinburne in the projects to be described have adopted a character of plant as the ideal method of generating fuel-power at the coal-field motive power generating stations, composed of the following constituent elements:—

First.—A gas generating plant of the cupola type, fitted with automatic fuel feeding devices and automatic reversal valve arrangements. The fuel is led by an electric overhead cable suspension way, or by means of an ordinary electric railway system, to coal bins from which it is elevated to the generators, and by electric driving gear is then transferred to each cupola.

Second.—The gas generated, is then led through a battery of condensers, in which any atomised fuel carried over with the gas is caught and by which the ammonia is separated as well as the tar. The purified gas is then led through scrubbers of the tower form, filled with coke or brush-wood, from which the residual tar and ammonia is finally removed. The sensible heat of the gases is then recovered by special means.

Third.—The gas is then led to the gasholder, and is stored for use. This advantage displaces the necessity for storage batteries. When the holder is raised to a certain height, it automatically turns off the gas generating plant by degrees. *A sufficient capacity for emergencies is always provided for.*

Fourth.—The ammonia water is treated with sulphuric acid by the formula $(2NH_3)+H_2SO_4=(NH_4)_2SO_4$, and the sulphate of ammonia recovered, is intended to be sold for agricultural purposes.

Comparative Efficiencies of Internal Power Transmission Arrangements.

The importance of the subject of the transmission of dynamic force to motive elements constituting the industrial plant, has only quite recently received some of that recognition which it deserves. The absorption of energy by shafting and belts is not even now properly appreciated. It is only when the dynamometer has been applied, and, better still, since direct driving by electric motors has displaced shafting gearing and belting

and other methods of driving—generally in use, that power users have realised the degree of ceaseless waste in their methods of power transmission.

The author has built up a diagram, see Plate 14, based on some data obtained from Mr. H. Flather's recent work on * "Dynamometers and the Measurement of Power"—a work that should be in the hands of every power user. This diagram alone is a lesson to engineering students.

The displacement by direct electric driving of ordinary shafting and belting methods has resulted in that reduction of power absorption very considerably.

M. Sarteaux, Engineer of the Chemin de Fer du Nord, has recently introduced electric driving at the locomotive workshops at Creil, and he has informed a mutual friend that he has realised a saving in power of 50 %.

This friend, in a letter, tells the author that some investigations carried out at the Fabrique d'Armes de St. Etienne proved that with their then shafting and belting methods of power transmission, not more than 7 % of the power consumed is utilised in doing actual work.

What is the explanation of this extraordinary waste which, if summed up for all our industrial applications, would almost turn the hair of our patriot economists grey ?

One may venture to suggest an answer—

The main shafting, having a potential of dynamic energy equal to the maximum requirements, is always in motion, each bearing surface in its length having a function of energy absorption depending in value upon the character and nature of the frictional surface.

Each location of transmission by belting to counter shafting is also a point of energy absorption, whether the effective part of the producing plant is in operation or not.

In dust-producing workshops the friction produced by the deposition of dust on the bearing surfaces, is alone a factor of explanation, and the loss of efficiency by imperfectly light and

* "Dynamometers and the Measurement of Power."—Flather.

unsuitable belting and intra methods of power distribution is also another factor.

The gearing elements for diverting the line of power transmission are also absorbers of energy.

Individual machines absorb much less power than is generally supposed, and the author urges every power user to ascertain precisely the amount of power absorbed by each of his machines. He would then be cognisant of the running loss by which he is the sufferer.

Since the author wrote the above he has seen the advance proofs of Mr. Saxon's useful paper.* Mr. Saxon pertinently remarks that if the coal consumption were based on actual work done it would give some startling results. There is little doubt but that M. Sarteaux's happy experience of a power saving of 50% by the application of direct electric driving would be experienced by many engineering workshop owners.

In Mr. Saxon's summary of tests it appears that the average energy absorption percentage for—

Spur geared driving is	25·9
Rope do. do.	29·6
Belt do. do.	28·6
Direct coupled do. do.	23·835

giving a total average of 26·983% of energy absorbed in internal power transmission work.

On referring to the diagrams of loss of energy, see Plates 9 and 10, in electric transmission methods, it will be realised that for any ordinary works there would be practically *no loss* of energy between the motor and the subsidiary industria machine.

The relatively high speed of electro motors is unfortunately not appropriate to existing stationary tools except by the employment of reducing motion pulleys ; but there is no obvious reason why the electric motor should not be applied direct to each new and convertible machine, the speed being reduced by helicoidal or other appropriate gear, to satisfy the requirements of the industrial operation.

* See paper on "Comparison of Friction in Cotton Mill Engines and Gearing to the actual work done," read Oct. 22nd, 1892.

Granting this desideratum, we have at once an ideal method of transmission which has the following series of valuable characteristics:

1st. Each industrial machine can be easily and instantly thrown out of dynamic action by the simple touch of a switch.

2nd. The loss of efficiency in power transmission from the parent motor is almost negligable.

3rd. No lubrication is involved, nor expensive lubricants.

4th. The dangers associated with belt shifting and belting set forth graphically in the author's work, *"Our Factories, Workshops, and Warehouses," are entirely removed.

5th. In the event of an accident the machine can be instantly arrested.

6th. As the power demand is cut off, the power supply is reduced in the same ratio.

7th. The position of the machine can be altered in any direction considered convenient, without involving the consideration of its effect upon the line of transmission.

8th. The danger from fire through over-heated bearings is reduced in a degree depending upon the quality of insulating workmanship and upon the character of the fusible cut off.

The employment of internal electric transmission has been in no instance in this country more fully put to regular use than by the famous firm at Wolverhampton—the Electric Construction Corporation, Limited; and for this progressive action we may thank Mr. Thomas Parker, than whom there is no more enthusiastic advocate of the practical advantages of electricity. Thanks to the courtesy of this firm, we are enabled to realise the extent of their practical patronage to electrical methods of power transmission. The full particulars are given in the appendix; but it may be stated here that *with the exception of one defect, that of the retention of intra or subsidary shafting and belting*, the whole of the power is transmitted electrically. The motors are distributed over four acres of ground, the same

* "Our Factories, Workshops, and Warehouses: Their Sanitary and Fire-resisting Arrangements."—London: E. & F. N. Spon, Charing Cross. By B. H. Thwaite.

cables distributing and transmitting the current for the motors, also supply the Arc and Incandescent Lamps for lighting the works.

All the machine tools, with the exception of a large planing machine and circular-saw (which have a motor of their own) are driven from shafting, rotated electrically. The 10-ton shop crane is also electrically driven. The cranes travel up and down the shop at the rate of 50 feet per minute, and cross the shop at the same speed.

The Electric Transmission Plant has now been running for two years. So far, there has not been any accident, and beyond the usual brush renewals for generating machines and motor transmitters, there have been no repairs required.

The firm completely relies on its motors, and has not provided any other means of driving the tools.

Not having driven the works by the ordinary methods, the firm cannot make any direct comparison as to power required, but the Secretary writes that there is no doubt but that a comparison would come out largely in favour of the electric method.

The De La Veigne Refrigerating Machinery Company, of New York City, have applied in their new works the electric method of transmitting power. They drive their extensive series of planing, slotting and drilling tools by separate motors of approximate size, gearing down by countershaft and belt; even with this disadvantage they consider that at least 7% of efficiency is gained, and the cost of maintenance is considerably less.

The Influence of Electric Transmission of Energy, if generally adopted, on the Atmosphere and on the Conditions of Life in Industrial Centres.

Anyone living in a purely agricultural locality, or in towns like Paris, where the ambient atmosphere is free from the polluted emanations from industrial processes, and having the misfortune to be compelled to remove therefrom to towns like Manchester, Bolton, or Oldham, must have been struck with the phenomenally high rainfall average of these towns, and will have noticed the characteristic oily condition of the

atmosphere (especially on wet and foggy days), and the greasy condition of the pavements.

Without going as far as Ruskin, one is compelled to admit that any industrial operation that tends to interfere with natural actions, by polluting the atmosphere and altering its degree of humidity, should be carefully looked into, to ascertain if the evil cannot be extirpated.

The atmosphere of Manchester having only a moderately high hygrometric character, acts nevertheless in the nature and with the effect of a condenser, for the immense volumes of steam sent into the atmosphere from thousands of exhaust pipes, until the ultimate or saturation point is reached, and the atmosphere being unable to hold in suspension this added aqueous vapour, it is released; the inevitable rainfall of Manchester follows, bringing with it the hydro-carbons belched forth from hundreds of chimneys. These hydro-carbons, along with the lubricant particles associated with the exhaust steam, explain the greasy condition of the mud in the Manchester streets.

How different is the early Sunday morn of these industrial centres! Every observer cannot fail to be impressed with the metamorphosis of the atmosphere.

The general distribution of electric energy for light and power, with fuel gas as the general heating agent, would go a long way towards clearing our industrial centres from these depressing conditions, so inimical to healthy vigour of mind, body and lightheartedness, and which conditions, so absurdly out of harmony with the characteristics of our once Merrie England, are not entirely free from responsibility in the cause of our National Shame of Drunkenness.

How different the Manchester of the once great Venetian Republic! There, the resultant wealth from the sale of the products of the looms of Lombardy actually adorned nature, and the architectural beauties of the Venetian industrial centres are to-day the joy of all art lovers, in almost spotless condition, except that charming tint due to antiquity; whereas the sculptured work in our industrial centres, as in the instance of Manchester, is simply a hideous caricature of the ideal of its architect creator.

The general distribution and use of electric power as proposed, along with the general employment of gas as the heating agent, would clear away this stigma from our cities and towns, and with it the dirty envelope of soot, that, once removed, would, let us hope, never be allowed to clothe up like a deadly pall the beauties of art in stone.

THE HYGIENIC ECONOMY.

The author demonstrated before the Demographic Section of the Hygienic Congress* that the expenditure in making any process or operation of industry thoroughly healthy was money well expended.

There is little doubt but that the facility of inducing currents of air, by means of electrically-propelled fans removes one of the disadvantages of the electric light, compared with a scientific system of gas burner; but, of course, the electric incandescent (in vacuo) glow light is far superior hygienically to the naked gas burner.

Comparing the two lights calormetrically, it will be seen that the heat produced for a given lighting or photometric value is far greater in even the scientific or recuperative gas burner than in the incandescent glow lamp. (Vide graphic diagram, plate 15.) Besides, with the latter system there is not the slightest pollution of the atmosphere. A diagram is also given, Plate 16, showing the thermo luminous efficiency of different methods of burning gas.

These are important advantages, because no cause is more prejudicial to vigour than expanded air resulting from an abnormal temp. The weight of air (oxygen) passed through the lungs is relatively less, and there is a drop in the animal vigour; the work done is less, and of inferior character.

With the distribution of electro-dynamic energy, a simple transformer attached to the service conductor will reduce the potential to the desired voltage degree, either for Arc or Glow Lamps. The increased vigour of the workpeople, due to the pure and relatively thermo-neutral light, its semblance to the

* "The Economics of Industrial Hygiene." The Proceedings of the International Congress of Hygiene, 1891 (Demographic Section).—*Industries, 1891.*

natural solar light in its actinic effect, will justify the employment of electric lighting alone, independently of the money value saved.

It has been conclusively proved in our Government Offices that labour is more efficient and the number of employés can be reduced, by the employment of lighting by electric energy.

The question of economy is dealt with elsewhere. It may, however, be expected that a greater luminous value, as 2·4 is to 7·7, can be produced by burning lighting town's gas in a gas motor, and converting the dynamic into electro-luminous energy, than in burning gas direct by a bat's wing burner. *Verb sap.*

The Value of a Supply of Economic Electric Energy to Agriculture and Floriculture.

The cultivator of flowers, fruit, and vegetables, has a friend in one of the characteristics of the Voltaic Arc light. This illuminant has an actinic, or chemically active-light effect, analogous to the light from unimpeded sunlight. This chemically active characteristic is the motive influence that initiates and stimulates organic life.

Ordinary artificial light from gas cannot be said to possess any electro-chemical influence.

In the Arc light we have nearly all the conditions that could be desired for the cultivation of fruit and flowers.

The sun is very sparingly permitted, by the conditions of our climate, to give us a bountiful supply of his invigorating electro thermo chemical energy. This has been proved by tests with actinically sensitive paper.

The influence of unimpeded sunlight is brilliantly shown in sunny California, where vegetable organic life is almost wantonly vigorous. It has long been known, since Sir W. Siemens' original experiments in this direction, that the electro-chemical energy of the Arc electric light is beneficial to the life and vigour of vegetation, but this beneficent advantage has only recently been put to actual industrial use; and again we have to point to the progressive American for the initiation of a practical commercial application of electro-chemical or actinic luminous energy for the rapid night-rearing of fruit and flowers.

Were the main high power electro-conduction trunk lines laid down through the heart of agricultural and pastoral England for the distribution of an additional supply of electro-chemical energy for a line of fruit and flower areas of cultivation, the benefit that would accrue, if properly and adequately utilised, would be an adequate justification for the expenditure.

Instead of the ordinary single crops, two, three, and even four crops might be obtained; and instead of our having to import fruit, there should be an excess over internal consumption that would permit an external fruit export trade to be opened up, not to mention the advantages to floral and horticulture.

THE THREE PROJECTS OF POWER TRANSMISSION.

The author and Mr. James Swinburne have drawn up the report of a project for transmitting power from the South Yorkshire coal-field to the Metropolis, see Plates 17 and 18. This report is given verbatim in the appendix, and is shewn clearly on the plan of trunk lines. It is, of course, obvious that the same trunk lines and way-leaves can be utilised for serving the large towns *en route*, including Derby, Nottingham, Leicester, Northampton, and Bedford. It is suggested that an auxiliary generating station shall be stationed in South Staffordshire, the trunk line from which shall serve Wolverhampton, Birmingham, and the industrial areas in the line of its route across to the point where it joins the main trunk line serving the Metropolis.

The respective losses of efficiency are shewn in the diagrams, Plates 19 and 20.

Two alternate specifications are given in the appendix, one by the Oerlikon Company, Maschinen Fabrik Oerlikon, to whose principal (M. Emil Huber) the author is indebted for much valuable information; and the other is contributed by Messrs. Brown, Boveri, and Company, and Mr. Charles Brown.

The other two projects are for supplying electro-motive force to the principal industrial centres of Lancashire and Yorkshire. For the Yorkshire one the Central Generating Station is located near Barnsley. The direction of the main trunk lines is clearly indicated in the plan of transmission. It will be seen to serve the industrial areas between Chesterfield and Sheffield in the

south and Leeds in the north, serving the Batley and Dewsbury district *en route*. A branch trunk line serves Huddersfield, Halifax, and Bradford, and their adjoining industrial areas.

The loss of efficiencies in the different trunk lines is clearly shewn by the Graphic Diagram, Plates 19 and 20. It will be seen to be a negligable quantity, and the interest on cost of mains would almost be covered by the mere cartage to the station in many instances, besides the great advantages already set forth.

The Lancashire Project Generating Station is located near Wigan, and here it may be mentioned that as the great power stations are all proposed to be located in the centre of the coal-fields, that this would enable the different colliery owners to obtain on satisfactory terms the unquestionable advantage of electro dynamic energy for traction pumping, winding, lighting, coal getting, ventilation, and drilling purposes.

One trunk line from the Wigan station will serve Bolton, Bury, Heywood, and Rochdale, and a loop line will serve Oldham, Stockport, Macclesfield, and Manchester. Another trunk line will serve Blackburn, Preston, and Clitheroe. A loop line branch will serve Accrington, Burnley, and the Rossendale and Haslingden Valleys.

A trunk line passing south from the station will supply St. Helens, Warrington, Runcorn, and Widnes, and a loop line will continue along the Ship Canal to serve the future industrial area of progressive Lancashire.

The author forecasted in the *Builder* ten years ago, that once the Canal was made, its banks would become the future area of new industrial developments, and with a line of power supply, a perfect railway connection and a means of over-sea transmission, it can be stated that no other area in the world would offer such facilities for cheap industrial production, as this area will be, with the supply of cheap electric and unlimited energy proposed.

To realise the marvellous industrial fecundity of Lancashire and Yorkshire, let us look at the diagram showing the proposed lines of electric power transmission as well as the lines of the telephonic system at present established. Here we have the nervous system of industrial life before us at a glance, the very

acmé of economy in transmitting thoughts. Let us go a step further and imitate nature by laying down a nervous industrial system to distribute power, and the picture, with the Ship Canal complete is perfect, and would be worthy of the enterprise of the counties of the Red and the White Rose.

THE APPLIED USES OF ELECTRIC ENERGY.

The area of application of electric energy is widening like the folds of an opening fan.

To merely enumerate the distinctive applied uses would almost fill up the time at our disposal. We will, however, briefly indicate a few of the more salient examples in the arts:—

The recovery of gold by electric amalgamation.

The production of aluminium.*

The cheapened production of phosphorous.

Extraction of metals.—Electro-plating.

Electro-Fusion.—Welding and the annealing of bars.†

Textiles and Dyeing.—Employment in sorting delicate colours, and for the tinctorial art by electrolytic decomposition.

Chemical.—The production of alkalies and chlorine by electrolysis, bleaching, tanning, and laboratory use.

The Art of War.—Flash signalling, luminous projection, firing repeating guns, and explosive work.

The Safety of Ocean Transit.—Signalling, controlling machinery for propulsion and steering, and ventilation.

Domestic.—For lighting, cooking, boiling, and heating.

Ventilation, knife cleaning, shoe brushing, nursery use, sewing machine driving, and for laundry work.

Agriculture.—Already described.

Engineering.—Partially described.

Commerce.—The transmission and repetition of thoughts and impulses enclosed in speech, by the telegraph, the telephone, and the phonograph.

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* Notes on Aluminium and its Production by Electrolysis and Electro-Fusion. By B. H. Thwaite. Proceedings Sheffield Metallurgical Society, 1891.

† Messrs. Clark, Chapman & Company, of Gateshead, have had, in almost hourly use, for the last two years, a complete electric welding plant. They also use the electric energy for their heavy travelling crane.

N.B.—The author has received information from, and now thanks the following firms and gentlemen, and his friend Mr. James Swinburne:—

M. Emil Huber, The Maschinen Fabrik, Oerlikon, bei Zurich.
Herr W. Lahmeyer, of W. Lahmeyer & Co., Frankfort.
Mr. C. E. L. Brown, of Messrs. Brown, Boveri & Co., Baden.
The Deutsche Elektrizitäts, Werke zu Sachen, Germany.
Mr. Thomas Parker, The Electric Construction Co., Wolverhampton.
The Crompton Electric Lighting Co., London.
Mr. Chas. Brown, of Bâle.
Mr. S. Russell, of Silvertown Cable Works, London.
Mr. J. Bailey, The Metropolitan Electric Supply Co., London.
And for certain of the Lantern Slides to Prof. Hele Shaw, Liverpool.
Messrs. Ashmore, Benson, Pease & Co., Ltd., Stockton.
Messrs. E. P. Allis & Co., Milwaukee, U.S.
The Editor of "Lighting," King William Street, London.

APPENDIX.

The Metropolitan Scheme for the Transmission of Electrical Power generated in the South Yorkshire Coal Fields.—*James Swinburne and B. H. Thwaite*

Description of the Electrical portion.

Generating Station, see Plate 6.—The motive power will be supplied by 86 gas engines, see Plate 7, each one capable of developing 300 brake horse-power. It may be advisable at some future time to adopt larger power engines than these, but as we know that gas engines of this size can now be made, it is not requisite to discuss the desirability of employing larger sizes for the present. Larger engines will, however, cost less in proportion to power, be more economic, and will be superior in many ways; thus it will be so much the better if we can adopt them instead.† The power will be converted by 18 alternating current generators, each of which will be coupled direct to two gas engines, so that there will be neither belts nor rope gearing. In order to *secure a higher and more regular condition of speed than that* of a three hundred horse gas engine, *both the armature and field magnets will revolve in opposite directions.* The armature will be driven by one engine, and the field by the other.

The dynamo Electric Generating Machines will be separately excited by three direct constant current Electric machines,

N.B.—† Gas Engine (Compound) of 1,000 I.H.P. can now be obtained to order.

coupled in series and driven direct by gas engines. Of these two will be able to excite the whole of the alternators, and the third will be ready as a spare one. The field magnets of the alternators will also be excited in series, so that their excitations, if it varies at all, varies simultaneously in all the machines. This will make it easier to secure a perfect condition of parallel running. In the daytime only one exciting dynamo will be run, and the other will be put into circuit as the load increases and more alternators are required. The independent adjustment of the excitation of the individual alternators will be effected by shunting the field magnets. This adjustment will be made once for all. This arrangement of the exciting circuits is to obviate the necessity of regulating the excitation which otherwise would arise when a cold machine is put in parallel with others whose fields have had time to become warm. The field magnets will not be wound with a single circuit in the usual way, but will have two circuits which are normally used in parallel. This allows the field magnets, which have a large self-induction, to be coupled into the series exciting circuit without causing a spark when the switch in shunt to it is opened. On starting, one of the field circuits is short circuited on itself, and the exciting current is started on the other. It causes a momentary current in the closed circuit, instead of making an arc at the switch. This dies away almost instantly, and the second circuit is then opened and put in parallel with the first.

The alternators will give 500 volts and 1000 ampères each, as a lower pressure would make the switchboard cumbrous and expensive, *and a dangerous tension is to be avoided in a station* as far as possible. The alternating system will be designed for single currents, and both the armatures and fields will be laminated to secure perfect control, when the machines are in parallel, in spite of the throb of the gas engines.

The switchboard will have two omnibus bars and two single 1,000 ampère switches for each dynamo, and the gear for controlling the excitation and the high-pressure circuits. To add a dynamo to the circuit, the switches short-circuiting its field, are opened as already described; its field is then excited to the normal extent; the engines are then run at the normal speed,

and one of the switches is closed, so that there is one pole to one omnibus bar. The other switch is now closed through a resistance which permits a large enough current to bring the dynamo into step, without any excessive strain. The second switch is then closed, and the machine is not only in parallel but is doing its adequate share of the work. Each generator has a wattmeter on the switchboard, so that it can be seen at once if the generator is giving its correct output. The gas supplied for the whole of the engines will be regulated by a speed governor, or it may be regulated automatically by mechanism depending on the frequency of the alternating currency, or by the hand of the man in charge. The gas for each engine will also be individually regulated. The engineer in charge can thus arrange what portion of the load is to be taken by each engine.

This will in practice be settled once for all, and the valve gears of the engines will be so arranged that they take equal volumes of gas and do equal work, the whole of them being under the control of the main station governor. Each engine will have a speed governor as well, but it will be set at a speed above the normal to avoid any chance of running away under any circumstances. The electromotive force of the station will be controlled by means of the exciting current, so that all the machines will be regulated together. The machine circuits will also have the usual double pole fuses.

The omnibus bars will be connected to a bank of large transformers, which will raise the pressure to 80,000 volts. One-third of these will be of the open circuit type, their exciting currents being supplied by the capacity current due to the long overhead conductors. The advantages of their higher all-day efficiency will thus be secured, and the complication due to the condenser action of the mains will be neutralised. The rest of the transformers, which will be in use for a few hours a day only, will be of the closed circuit type, designed for constant heavy loads. The transformers will be oil insulated, or the arrangement introduced by Mr. Kolben, of the Maschinen Fabrik Oerlikon, will be employed.

The transformers will have switches and double pole fuses on both circuits.

In cutting a transformer out of circuit the high pressure switches will first be opened. The fuses will also be arranged so that in case of any short circuit the high pressure circuit is first broken, so that there will be no 30,000 volt arc.

The leads will be bare conductors carried overhead on poles. There will be three positive and three negative leads, an initial pressure of 30,000 volts being used. The middle of the circuit will not be earthed at the stations, but electrostatic devices will be arranged to alarm if the middle of the circuit varies from the potential of the earth. In the case of a partial earth on any conductor, that conductor will be instantly earthed automatically and cut out of circuit at both ends.

The positive and negative leads will be arranged so as to be the same height. There will thus be no capacity currents induced which might affect telephone trunk lines.

The overhead conductors will be carried on creosoted wooden poles at a height of 30 feet from the ground at lowest points in summer. Oil insulators will be used.

At short distances along the lines, lightning arresters will be arranged on the poles.

The brackets for supporting the insulators will be metallically connected to earth by the lightning conductor on each post, so that if there were a leak at one insulator there would be no fall of potential along the post, which might be dangerous to anyone touching it. The upper pairs of wires will be arranged further apart than the lower, so that if one is fused by lightning or breaks it will fall clear of the others.

The use of the upper pair of wires will be avoided as far as possible during thunderstorms, and to admit of this more readily they will be smaller than the others.

In addition to the power conductors, telephone wires will be carried on the same poles. There will also be a special small wire for localising faults by the loop test.

At intervals along the line there will be guard stations. There will be small dwelling-houses near the line, into which the telephone and testing circuits are led.

A fault can be located much more accurately from a guard house than from one of the stations, and a man can go and change the insulator at once, and remove anything that may have fallen against the main.

The receiving station will be on the north side of London, and will only contain the step down transformers and a switchboard. One-third of these transformers will have open circuits, and will have their exciting currents supplied by the capacity of the lines, and the rest will be of the closed circuit type, as before. They will transform down to 2,000 volts, and in some cases to 5,000 volts. Circuits will be led from this station to the premises of the various Electrical Supply Companies of the Metropolis. Those which employ 2,000 volt distribution will substitute a distributing switchboard for their central stations. In cases where the mains are in a net, the connection will be made direct to the mains.

Where separate circuits are preferred, one to one transformers will be used to secure insulation, and the ratio will be adjustable if desired. Small direct current stations will be supplied with alternating currents, and will remove their plant and transform down to the pressure they require. If the engineers cling to direct currents, they can put alternating current motors down to run their direct current machines. Their engines, boilers, and batteries will, of course, be no longer necessary. Large direct current stations that employ feeders can either use alternating currents on the same system, or can have a number of small sub-stations; or they can have feeder transformers manipulated from our station.

It will be best for the existing electrical supply companies to amalgamate with one another and with us, and, in fact, to cease to have any separate existence. The whole of the Metropolis can then be worked direct with less expense. This would demand a large capital, though the supply companies will not need engines, boilers, batteries, or dynamos. These are only a small matter. Low pressure mains demand a great deal of capital. Where mains already exist, new capital need be found only for increasing the electrical supply; and whether amalgamations could be brought about is a financial question only.

The cost of the plant for 10,000 H.P. comes out as follows:—

20 Gas Generators	£8,000	
Steam Generators	1,500	
Automatic Fuel Conveyors	1,000	
Electricway-Motor Sidings	1,200	
Liquor Tanks	6,200	
Two Gas Holders	16,800	
Two Tanks	15,000	
Dust vessels	500	
Condensers and Sulphate of Ammonia plant	4,000	
		54,200
37 Gas Engines	31,600	
18 Dynamo Electric Machines	35,000	
Exciters and Engines	2,000	
Transformers	12,000	
Switchboard and Gear	3,000	
		83,600
Line, including Poles and Insulato ..		80,000
Receiving Switchboard	3,000	
Receiving Transformers	10,000	
Connecting Mains in London	10,000	
		23,000
		£240,800

Besides the cost of the land, *which will be a very nominal sum compared with the cost of land near populous centres*, and the necessary buildings, there are various contingencies to be met, such as the possible necessity of underground mains across railways. The costs of way leaves, and perhaps of Parliamentary powers, must be faced, so it will be necessary to have a paid-up capital of some £400,000, and in order to make it worth while to carry out this scheme, there must be a prospect of a handsome profit on £400,000 with a maximum output of 10,000 horse-power at the generating station.

Taking the maximum output at 10,000 horse-power, or 7,500,000 watts, the maximum power in London will be 5,400,000 watts.

On the assumption that our first power is used for lighting and almost no motors are used, enough lighting can be taken up to utilize 5,000,000 watts during a heavy fog. This corresponds with a low average load throughout the year, and it will probably be safe to assume an average consumption of 1,000,000 watts only.

The loss in the leads varies as the square of the current, so the effective current throughout the year must be taken. It will be necessary to generate about 1,060,000 watts at the station,

as an average throughout the year. Taking the cost of coal at 4s. 6d. per ton, after deducting the value resulting from the distillation and complete recovery of residuals, this will cost £1,100 per annum.

The cost of power per year may be taken thus :—

Coal	£1,100	
Oil and Sundries	1,000	
Labour	1,200	
		£3,300

The cost of generating, exclusive of interest, depreciation, and standing charges, thus comes out at less than a tenth of a penny per kilowatt hour. The selling price may be taken as follows :—

Cost of generation	£3,300
Trade expenses	3,300
Depreciation on plant at 5 per cent.	12,500
Interest on Capital, making 7½ per cent dividends ..	30,000
	£49,100

This amounts to 1·84 penny per kilowatt hour. It must be remembered that 5% is a high rate of depreciation in a case where an average of six-sevenths of the machinery is idle. 1·84 penny per kilowatt hour is the selling price to the local supply companies. They have to add the depreciation on their transformers and distributing mains and motors, and the interest on the capital invested in them, and the cost of collecting small accounts. As the prices in London vary from 6d. to 8d. per kilowatt hour, there is obviously an ample margin. We are not so much concerned with what the companies charge their customers as with what they will pay us. It costs them at present more than 1·84d. per kilowatt hour for coal, oil, and labour, without taking depreciation, trade expenses, and profits into account. It would therefore pay them to take power at considerably over our price, say 2½d.; and, rather than add more plant in the case of extensions, it would pay them to give even more.

In the above case the worst conditions, those of lighting a city subject to fogs, have been taken. Power taken constantly, can be supplied at a much lower rate. Factory engines run about 54 hours a week, and the load factor of a large number of engines can thus be taken at about one-third. We can therefore supply power in large quantities at 0·65d. per horse power

hour, notwithstanding the power load overlapping the maximum lighting supply. Large steam engines can develop power at less than 0·65d. per horse power hour ; but it must be remembered that the power actually used is only a small fraction of the brake horse power of an engine. In addition to this, an engine and boiler with a varying load works very inefficiently. An engine and boiler in a factory can therefore be replaced by electric motors of very much smaller nominal power, as the elaborate systems of countershafting and belts can be avoided. In addition to this the efficiency of a motor is fairly high on light loads, and the motors need never run idle.

Specification of 10,000-h.p. Electric Power Transmission Plant from the Yorkshire Coal Fields to the Metropolis: Length, 192 Kilometres (120 miles).

C. E. L. Brown, of Brown, Boveri, & Co., Baden.

Power Generating Plant.—Twenty Otto Cycle gas-engines of 500 to 600-H.P. each arranged so that when the latter are working at their maximum load and the whole 10,000-H.P. is required, there are still three engines in reserve; engine speed to be 160 revs.

Electric Generating Plant.—Twenty (two-phasic) Alternating Current Machines, each for 600-H.P., together with their transformers, for stepping up the current to 20,000 volts.

The generating machines would be regulated by exciter current governors, and so arranged that there is one governor to each electric generating machine capable of governing its own generating machine alone, or of being coupled up by means of a hand wheel on the switch-board, to act in common with the other governors.

Exciting Machines.—Three continuous current electric generating machines to act as exciters, of 120-H.P. each. Two of these exciting machines are capable of exciting 20 of the alternating generators. Each exciter would be coupled up to a separate gas-engine of suitable power.

Switch-board.—Switch-board, containing all the necessary apparatus for measuring, regulating, and safety purposes.

There will be a double switch, a double lead safety fuse, an ampère meter for each group of engines, a volt meter, the requisite parallel shunting apparatus, and, in addition, a general ampère meter for the whole installation, as well as a general volt meter.

Trunk Cables.—Cables to be 192 kilometres long (120 miles), rigged overhead, to be four in number of a section of 800 square millimetres. The total loss of efficiency in the entire length of cables is estimated at 20%. It is desirable to split up the four mains into six wires, each of eight millimetres diameter; so that in all there would be 24 wires each a sectional area of eight millimetres.

Secondary Transformers.—The transformers to have a capacity of 5,400,000 watts. The total cost of the plant specified may be taken at £53,000 without cables and erection. The total efficiency of the system will be 70%. Including the cables the cost will £250,000.

Mr. Charles Brown estimates that the entire cost of the undertaking, including, gas power plant, buildings, land, and £60,000 for contingencies, will be £340,000; and on this this basis of cost he estimates that, allowing *for interest* and amortisation, small users can be supplied in the Metropolis of Greater London with one H.P. per annum for £4 10s.

THE SPECIFICATION OF THE MASCHINEN FABRIKEN OERLIKON. SOUTH YORKSHIRE TO THE METROPOLIS.

Electric Generating Machines.—Five generating machines, with one in reserve erected on the Triphasic Alternator system, each machine being of 2,500 H.P., with a speed of 350 revolutions. The horizontal axis of machine to permit of direct driving.

Exciting Machine.—Two exciting machines, with one in reserve, each capable of exciting four generating machines. The exciting machines to be on the shunt principle, and to have an E.M.P. of 158 H.P., giving

1,600 ampères at 75 volts, with a velocity of 400 revolutions per minute.

Transformers.—Ten transformers (with two in reserve) for triphasic currents, each of a capacity of 850 kilowatts, and each one capable of elevating the tension up to 20,000 volts.

Commutation Tables.—Five commutation tables, with the controlling apparatus for safety and measurement controlled therein, as well as the conductors and the insulators for the installation of the generating station. Efficiency of the generating station, 90%.

Lines of Transmission.—High tension, with a total capacity of 63,720 kilowatts, corresponding to 10,000 H.P., to transmit at a distance of 120 miles, with a loss first of 20% and second of 30%.

First, with a loss of 20% at an initial pressure of 20,000 volts, three conductors of a section of $360^{m}/_{m^2}$, corresponding to 12 conductors of a section of $90^{m}/_{m^2}$.

Second, with a loss of 30%, three conductors of a section of $240^{m}/_{m^2}$ corresponding to nine conductors of a section of $78^{m}/_{m^2}$.

Oil insulators on the Oerlikon system to be adopted as applied at Frankfort, as well as the necessary safety and regulating arrangements. Total cost of electric part, including transformers, is made up as follows:—

Electric Plant of Generating and Transformer Stations	£36,000
Conductor Trunk Line (120 miles) with 20 per cent. loss	153,000
Total	189,000
Cost of Power Plant	85,800
Total	£274,800
Then add for contingencies	60,000
Grand total equals	£334,80

An Approximate Estimate of Cost of Transmitting Fuel Power Energy by Rail and Cart to the Metropolis from Yorkshire.

The peculiar character of the coal traffic prevents the coal carrying rolling stock, from being utilised on the return journey, so that the double journey has to be performed with the almost unlimited and merciless shunting operations involved. There

can be little question but that this portion of the rolling stock does more damage to the permanent way than all the rest of the goods traffic.

The cost of conveying coal to London may be approximately estimated to be made up as follows:—

Merchant's profits, cost of cartage per ton at both ends, varying from 2s. to 5s., say	3	6
Railway rate, varying from 6s. to 8s., say.....	7	0
Value of coal at the pit's mouth, 4s to 8s., say ..	6	0
	16	6

Assuming with electric plant a 10,000-h.p. initial production, with a terminal output of 7,000-H.P., and allowing for a continuous full load work for 7,000 hours out of the total of 8,760 hours per annum, then the cost, direct and incidental, of rail and cart transmission for supplying this 7,000-H.P. at the Metropolis, and estimating a fuel absorption of 2½lbs. of coal per H.P., would be made up as follows:—

$$\frac{7{,}000 \times 2{\cdot}5 \times 7{,}000}{2{,}240} \times 10\text{s. } 6\text{d.} = £28{,}710 \text{ per annum.}$$

This, capitalised at a reasonable interest, appropriate to such a secure investment of capital, would alone justify a total expenditure on power generating plant and trunk lines of transmission of £500,000. (See diagrams, Plates 21 and 22.)

Particulars of Electric Transmission of Power Plant at the Electric Construction Corporation's Works, Wolverhampton.

Electric Generators.—Two Shunt-wound Dynamos, each capable of giving 110 volts, 750 ampères, at 400 revolutions. The lighting of the works is supplied from the same dynamos as the power. During winter months, when the lighting plant is in action, the two dynamos are run in parallel, but for supplying power only one machine is always in action.

Electric Motors.—The following is a list of the Motors in use:

Three Motors are driving 10 ton Travelling Cranes.
Two ,, ,, 5 ,, ,,
One Motor is ,, a Root's Blower supplying air blast to Cupolas and Smith's hearths.
One Motor is driving a Circular saw.
One ,, ,, Planing machine.

Nine Motors are driving the counter-shafting from which the tools are driven.

Two small Motors, one for driving a small Lathe and Drills for instrument making, and the other for polishing bobs.

Electric Power Distribution.—The Motors are distributed over about five acres of ground. The same cables that lead the current for the motors also supply the Arc and Incandescent Glow Lamps for lighting the works.

Counter-Shafting.—All the machine tools, with the exception of a large Planing Machine and one Circular Saw (each of which have a motor of their own) are driven from counter-shafting, which is 2½in. diameter throughout. The main lines of shafting are about 250 feet in length, on each of which there are two motors. These motors run at a speed of 500 revolutions per minute, and drive by belt on to the counter-shafting, which runs at 120 revolutions. The motors share the load, and regulate themselves. The length of shafting at present in use is some 1,200 feet. There are 164 tools driven from shafting, many of them being very large.

Voltage and Amperage Power.—The average output from the Electric Generator supplying all the above motors, is 110 volts, 500 ampères.

Cranes.—The 10-ton cranes are arranged to travel up and down the shop at a speed of 50 feet per minute, and across the shop at the same speed. With the fast gear they lift at a speed of 9 feet per minute, and with slow gear at 4·5 feet per minute. Some tests taken soon after the cranes were erected, and with all parts new, gave the following figures:—

Lifting 7 tons, slow gear	motor absorbed	70	ampères	106	volts.
Lowering ,, ,, ,, ,,		26	,,	108	,,
Lifting empty, rapid gear	,, ,,	18	,,	110	,,
Lowering ,, ,, ,, ,,		8	,,	110	,,
Travelling along the shops	,, ,,	20	,,	109	,,
Lifting 9 tons, slow gear	,, ,,	110	,,	105	,,
Lowering ,, ,, ,, ,,		50	,,	110	,,
Travelling along shops with 9 ton load,		25	,,	110	,,
Travelling across ,, ,, ,,		25	,,	110	,,

Planing Machine.—A large planing machine, capable of planing 20ft. by 12ft. by 8ft. high, and having a travelling table weighing 17 tons, is driven by an independent motor. When planing up an ordinary bedplate casting, the electric energy taken in forward cutting averages some 105 volts 80 ampères, and absorbs slightly less than this on the return motion, but at the moment of reversal at each end of the travel, the power absorbed increases to 105 volts 100 ampères.

General.—The electric transmission plant has now been running in these works for almost two years. So far there has not been any accident, and no repairs have been as yet required beyond the renewal of brushes for the dynamo and motors.

Electric Locomotive.—The photograph lanternly exhibited represents a small Electric Locomotive in use on the surface at a colliery in the neighbourhood of Wolverhampton. The current is supplied at a potential of 300 volts, by means of a bare copper wire (4 gauge) carried by insulators from poles; the return circuit is made through the ordinary rails. The power is nominally equivalent to 9 H.P., but the machine works up to twice this power for short periods, when taking a heavy load (six tubs) up the steepest gradients.

The Tivoli-Rome Electric Transmission Installation, Supplying Rome (Italy) 18½ Miles away with Electric Energy for Power and Light.

A few notes respecting this remarkable installation are interesting, if only merely for reference.

Here we have an example of generating electric energy from hydraulic power, that fairly couples the engineering triumphs of the antique with those of to-day.

On the actual site of the villas of the Patrician Romans, including that of the palace in which a beautiful Roman lady received her lover, the unscrupulous and mad Nero, we have a modern electric generating station, driven by hydraulic power from the water flowing through those monuments of Roman engineering skill, the aqueducts, that once supplied Rome with water.

The aqueduct or canal terminates in a tower, in which there is a stand-pipe of sheet-iron 125ft. high by 5ft. in diameter. Three groups of Ganz-type turbines, each group comprising two 320-

H.P. turbines, and three turbines of 50-H.P. convert the hydraulic fall into dynamic rotary power. Each of the larger turbines drives an alternate-current machine, which at 170 revolutions per minute supplies a current of 42 ampères at a potential of 5,100 volts, equal to 273-H.P. The magnet wheel of alternator is 7·2ft. diameter, and contains 30 poles. The smaller 50-H.P. turbines are coupled direct to a 4-pole exciter running at 375 revolutions per minute, providing a current of 150 ampères at 180 volts electro-motive force.

The exciters are arranged in parallel, and they are equipped with hand rheostats. The regulation is effected by two automatic rheostats, of the Blethy type, in the field circuit of the exciting machines. These rheostats are so arranged that the E.M.F. of the 16 transformers working in parallel, form a group that transforms the 4,000 volts pressure current into one of 2,000 volts, and transmits the current from the Tivoli aerial conductors to the underground network of conductor cables, that distribute the electric energy throughout the streets of Rome. The effect of loss in the line is balanced by an equaliser. Switching out the main, and breaking the circuit, is effected by the use of a load resistance-rheostat, composed of 87 miles of iron wire.

The transmission conductors consist of four copper cables of 19 wires each. The cables are so arranged, that they can be exchanged at will, in the event of accident or when repairs are necessary.

Three of the cables are sufficient for conveying the total energy of the generating station Two wires carry two-thirds of the load. The total efficiency is 80%, or a loss of 20%, the exact loss being stated to be 1,020 volts out of an initial pressure of 5,100 volts.

The transmission cables are attached to very strong oil insulators, placed upon iron and wood poles erected at distances of 115 to 130 feet apart. The same line of poles carries silician bronze wires for telegraphic and telephonic purposes. The lowest cable is 25ft. above the ground.

The central station in Rome, 18½ miles from Tivoli, is operated at a pressure of 2,000 volts, the Tivolian potential

energy being reduced to this pressure by cable resistance, and 32 transformers, each of 25,000 watts capacity.

At present 250 Arc lights are in use, but this number can be increased up to 600. These lights are arranged in series of 45 each, the conductor aerial lines being of copper wire, four millimetres in diameter.

Each large step-down transformer provides a current of 14 ampères at 2,000 volts, for each group of 45 Arc lights. Fourteen such transformers feed 14 Arc light currents, or 600 Lamps. In each of these circuits the automatic rheostats establish a constant current potential of 14 ampères.

The Cost of Electric Motor Generators compared with that of Steam and Gas Engines.

It may be interesting and useful to compare the relative cost of the three methods of generating power, that is with a steam-engine, a gas-engine, and an electric motor, from the point of view of the consumer, and based on German practice as interpreted by Professor Salomon and Herr Redner. (See diagram Plate 23.)

In German small power steam-engine practice of the non-condensing type, 4 kilos. of coal are absorbed per I.H.P., that is 8·80lbs., and for the larger powers the average may be taken at 2½ kilos., or 5·50lbs., per I.H.P. per hour. Working 1,500 hours per annum, and using town's lighting gas for driving gas motor, it is found that up to 15 I.H.P., driven with this comparatively costly gas, gas-engine power is the cheapest; but the margin of advantage gradually falls until for 2·5 I.H.P. it disappears, and is then only equal to steam; but where the time worked is 3,000 hours per annum, the gas-engine is the cheapest form of motor generator all along the line.

With electrically-conveyed dynamic energy, the absorption of work need only be in proportion to work done, whereas with the steam-engine the full load is practically always on.

Herr Redner has established the cost of completely installing a line of motors varying in power from 1 to 25 H.P. It may be stated that the cost exceeds English practice, but the ratios are, however usefully comparable.

	Power of Motor—			
	H.P. 1	H.P. 10	H.P. 15	H.P. 25
Steam-engine—				
Marks	1550—£75·9 ..	M6800—£333 ..	M8300—£406 ..	M12000—£636
Gas Motors—				
Marks	1810—£88·6 ..	M6300—£308 ..	M8200—£401 ..	M10200—£504
Electric Motors—				
Marks	650—£31·8 ..	M2100—£102 ..	M2520—£123 ..	M3980—£195

In the cost of maintenance, including the yearly expense involved in repairs, interest, and amortisation, the electric motor generator is very much less than either that of steam or gas. Here are Herr Redner's figures:—

	Motive Power—			
	H.P. 1	H.P. 10	H.P. 15	H.P. 25
Steam-engine—				
Marks	232·50—£11·38 ..	M1020—£49 ..	M1245—£60·9 ..	M1800—£88
Gas Motors—				
Marks	271·50—£13·3 ..	M945—£46 ..	M1230—£60 ..	M1530—£75
Electric Motor Generators—				
Marks	105· —£5·14 ..	M350—£17·1 ..	M440—£21·5 ..	M575—£28

Herr Professor Salomon is of opinion that for steam-engines 5% should be allowed for interest, 8 to 9% for depreciation, and 1 to 3 % for repairs.

It may be noted here that at Bockenheim, the electric motors are hired out. The relative portable character of the electric motor and generator lends itself admirably for the convenient and often economically advantageous hiring-out system.

ELECTRIC TRACTION.

One of the industrial applications that awaits fuller development is that of heavy electric traction for high speeds and long distances, and whilst locomotives with electric propelling gear are being built in both America and Europe of equal tractive power to an ordinary passenger steam-driven locomotive, a practical and progressive step in the development of the application of electric enery exists in the South London Electric Railway. The history of this underground addition to the Metropolitan railway system has removed any possible objections that could have been raised against practicable electrically propelled locomotives. With the exception of a few negligable

minor difficulties, the application has been a solid success, both financially, hygienically, and thermo-dynamical—the latter efficiency is 800% greater than the ordinary locomotive practice.

The following are leading factors of experience in this application :—

Running speed per hour, 13·25 miles.

Mean ampères from Stockwell to City	50·33
Do. volts do. do.	424·16
Mean ampères from City to Stockwell	48·72
Do. volts do. do.	425·26

Running speed per hour, 12·7 miles.

In these electric locomotives the armature coils are wound directly on to the axles of the locomotive wheels, and the locomotives built by Messrs. Beyer, Peacock, and Co., Ltd., Manchester, weigh 13½ tons.

The original conception of this simple method of driving is traceable to Sir W. Siemens. The motor currents are collected from a central rail by means of a sliding contact shoe, fitted at each end of locomotive. The initial torque, or starting energy, is 140 ampères.

Ordinary train driving by electric energy is in common use in the United States, and in its overhead conductor mains the efficiency is said to be satisfactory. The same principle has been adopted by the Liverpool Overhead Railway.

Underground mine electric traction is now successfully employed in many mines in Europe and America, and offers great advantages over former systems. The same principle of dynamic transmission is adopted for winding purposes.

The traction of canal boats only awaits development to bring a wanted stimulus to this excellent inland method of transmitting cargo.

The Financial Risk Involved in Laying Down Long Lengths of Electric Conductors.

It will be recognised that for long distance lines of transmission the cost of installation and plant is made up in a very considerable proportion by the electric conductor mains. Hence the consideration of the risk of value depreciation of this proportion is of first-class importance.

Fortunately, the bulk of the cost is in the purchase of a character of conductor metal that forms one element in our coinage, and is of such a character that, exposed to ordinary atmospheric or subterraneous conditions, and unlike gas or water pipes, it suffers very little, if indeed any, appreciable depreciation. The copper will weigh as much at the end of the term of 20 years as when originally laid down. The labour proportion associated with this element is practically *nil*. Hence the question arises—What is the fair rate of interest that should be charged on an element possessing such a high degree of financial security?

To answer this with adequacy of response, we must first examine the extent of the fluctuations of the price of copper for the last 10 years, in which period, owing to the abnormal extension of its use, a rare degree of variation of demand has arisen. These fluctuations are clearly shewn in the graphic diagram, Plate 24, and by the table given in the Appendix. The author has drawn along the diagram a line of average value.

Copper leads or wire purchased at a value falling below this line of average value may have a possible depreciative fluctuation of 2·5 in 7, equal to 36% of its par value. This average ratio of risk can now be compared with those of the Bank rate of interest, that of the Railway Ordinary Stock and the Government Stock.

In the research fixing these latter rates, the author is indebted to the kindness of the editor of the *Financial News*. He writes that in the 10 years ending 1891 the Bank rate has varied from 2 to 6%, the average rate being, perhaps, $3\frac{1}{8}$%. On Railway Ordinary Stock the average return at the existing quotations was about $3\frac{1}{4}$%, and during this same period the average Government return was about $2\frac{7}{8}$%, so that, adding these rates of interest together and striking a final average, we obtain the figure $3\frac{3}{16}$%.

This rate, the author proposes, would be a fair rate of interest for the class of security represented by large weights of copper conductors. The author further ventures to suggest that this part of the capital, or the part to cover the cost of trunk trans-

mission lines, should be obtained by the special issue of mortgage debentures at the rate of interest stipulated.

American Steam-engine High Power. Latest Practice for Central Station Work.

The author is favoured with the following particulars respecting the latest steam high power practice from Messrs. E. P. Allis and Company, Reliance Works, Milwaukee, Wisconsin:—

The 8,500-N.H.P. West End Street Railway Station at Boston, Mass., is equipped with eight triple expansion condensing engines, having cylinders 23, 36, and 52 inches diameter by 48 inches stroke; and one triple expansion condensing engine, having cylinders 16, 24, and 36 inches diameter by 48 inches stroke. The larger machines are rated at 1,000-H.P. under normal conditions, and the smaller machine at 500-H.P. All steam cylinders are steam jacketed on their sides and heads; the initial steam pressure is 160 pounds to the square inch.

Each engine is provided with a Wheeler Admiralty surface condenser, with air and circulating pumps operated by independent steam-power.

The fly-wheels for large engines are 28ft. diameter by 127in. face, and each one weighs some 60 tons. These engines are located in two stations, one station having six of the large engines and the other station two of the large engines and the smaller machine.

Each set of three engines is belted to a line shaft located in a shaft alley, and the electric generators are operated from pulleys located on this line shaft. Each section of shaft is 40ft. in length by 10in. diameter, with the large pulley receiving the belt from the engines located in the centre of each section. On each side of this pulley and on each section are located two pulleys for driving generators, so that any one engine and its section of shaft can be cut out of the main line and four generators driven separately in this way, or the whole system can be coupled up together by friction clutches. This firm is now equipping two stations for the Brooklyn City Street Railway Company, Brooklyn, N.Y., one station to have cross compound condensing engines with cylinders 26in. and 48in. diameter by 48in. stroke to run with 160lbs. steam pressure, each engine to

operate two electric generators belted direct from the fly-wheel, *without the use of a line shaft.*

The same firm is furnishing eight engines of this description for the South Station, and six engines of 2,000-H.P. each for the North Station. These latter machines will have cylinders 32in. and 62in. diameter by 60in. stroke. They will be cross compound steam jacketed engines, and have a 2,500-H.P. electric generator belted on the crank shaft.

This is the first large station of this description built in this country. The generators are now being constructed by the Thomson-Houston Electric Company, Lynn, Mass.

All the Brooklyn engines are to be furnished with surface condensers, air and circulating pumps, the smaller engines having the latter driven by a lever movement from the crank-pin, and the larger engines will have independent steam-power operated air and circulating pumps.

The Long Distance Test of 112 Miles Electric Transmission of Power between Lauffen and Frankfort.

Designed by Herr M. Von Doliro Dobrowolsky.

As this test may be said to have been the pioneer of long distance transmission projects, concise data relating to it may be useful for reference:—

Original Power.—The original power was a 300-H.P. turbine.

Electric Generator.—The electric generator was a C. E. L. Brown three-phasic type machine, made by the Maschinen Fabrik Oerlikon.

N.B.—A diagram of the field is given (see Plate 11).

Transformer Step-up.—The voltage was increased by three transformers at the supply or Lauffen end, and decreased at the demand or Frankfort end. The ratio of transformers was 1-160. They were of the Oerlikon oil insulated type.

The current was conducted by three bare hard drawn copper conductors of 160 millimetres diameter.

The line poles were placed at distances of 200ft. The current drove at Frankfort a 100-H.P. three-

phasic electric motor, besides providing part of the energy for lighting.

The equalisation of the pressure on the Brown Oerlikon electric generator is effected by the adjustment of the degree of excitation, and for this purpose it is equipped with a rheostat.

Line Circuit Arrangement.—The circuit arrangement is explicable by reference to the graphic diagrammatic outline (see Plate 25).

Elements are indicated thus :—

Three-phasic alternator... A reference letter.
Step-up transformer ..... B ,, ,,
Step-down ,, ... C ,, ,,
Volt metres .....Reference letter Vm1.
,, ... Vm2.
,, ... Vm3.
Ampère metres..... Am1.
,, ... Am2.
,, ... Am3.
Safety Fuses .....SF_1 SF_2 SF_3
Relay Magnets .....RM_1 RM_2 RM_3

Coils represented by a_1 a_2 and a_3 for Alternator.
,, ,, b_1 b_2 and b_3 for Step-up Transformer B Primary Coils (low presure). Full line.
,, ,, p_1 p_2 and p_3 for Step-up Transformer B Secondary Coils (high pressure). Dotted line.
,, ,, s_1 s_2 and s_3 for Step-down Transformer C Primary Coil (high pressure). Dotted line.

Intra connections of generating station—

N.B.—Coils a-1, a-2, a-3 of A Alternator, radiated from centre at an angle of 120 degrees.

The A Alternator Coil a-1 is coupled up to Coil b-1 of Transformer B.
,, ,, a-2 ,, ,, b-2 ,, B.
,, ,, a-3 ,, ,, b-3 ,, B.

The B Step-up Transformer Coil 1p is coupled up to Coil s-1 of Step-down Transformer C.

„ „ „ 2p „ „ s-2 „

„ „ „ 3p „ „ s-3 „

The return connections are double, one being by insulated conductor currents, shewn by full line; the other connections are also double, one being by earth.

The insulated conductor currents are equipped with—

	Ampère Metres shewn by	Am1	Am2	Am3
and with	Relay Magnets	„	Rm1	Rm2	Rm3
„	Safety Fuses	„	SF_1	SF_2	SF_3
„	Volt Metres	„	Vm_1	Vm_2	Vm_3

The equalisation of the three-phasic currents is effected by relay magnets, which are arranged for maxima and minima currents.

If the proportions of the currents in any branch of the three-phasic alternate currents should be inefficient or below the normal degree, or exceed the maxima for which the relay magnets are adjusted, the (R.M.) relay magnet breaks the connection between the exciting generator and the magnetic field of the alternator. The voltage of the low pressure circuit of the generator is consequently a function of the residual or latent magnetism of the three-phasic alternator, and is consequently quite safe, even should the primary connections become short circuited.

Regulating and Measuring Arrangements.—The regulating gear is shown by the lantern slides, and consists of the usual fuses, relays, ampère meters and volt meters of the initial current, which were mounted upon switchboard, along with the volt meter and the ampère meter of the exciting current generators and their own rheostats.

The compensation of the resistance on the line was established as follows:—

The primary voltages of the various currents were tabulated, and the table drawn up was employed by

ocular reference to maintain a constant pressure at Frankfort.

When the load was taken off at Frankfort the turbine at Lauffen commenced to race, and the hydraulic pressure was at once diverted.

The Oerlikon firm fixed up a novel line fuse arrangement as follows:—A short length of circuit was established across two upright poles, placed some seven or eight feet apart, with corresponding wires to those of the main trunk line, but only some six millimetres in diameter.

In order to indicate from Frankfort that the generating machinery could be stopped, a simple but effectual short circuiting arrangement was provided at Frankfort. This consisted of the suspension over the conductor trunk lines of a piece of iron so shaped that when lowered it came simultaneously into contact with the three conductor mains. The result was the fusing of the resistance fuse wires at Lauffen, and this indicated to the Lauffen man that he should stop the machinery of electric generation. After fusion occurred the telephonic connections were switched on, and vocal communication was established along the trunk lines.

It was found that as long as the short circuiting was established the telephonic communication could be carried on, even if the generating machinery at Lauffen was started during vocal inter-communication. The poles carrying the resistance wires were provided with steps to allow of the rapid replacing of these wires.

Safety Arrangements.—The safety arrangements were simple and well thought out. Referring to the step-down transformer C, it will be noticed that the junctions of the high pressure coils S_1 S_2 and S_3 were coupled to the junctions of the low pressure coils L_1 L_2 and L_3 by fuses S F_4, and the same remarks apply to the transformer B. By this means there was established a permanent earth connection between the entire electric system.

Assuming that any one of the three wires constituting the conductors broke down and fell to the ground, the latter would at once transmit its current to the earth, and its fuse ($S F_4$) would melt, cutting out the line and starting the corresponding relay magnet (R.M.) in action, which would disconnect the exciter from its corresponding coils in the alternator A, and the pressure would then be restored to the safety limits of the power transmitting station.

Additional Notes re Loss of Dynamic Energy in Internal Transmission of Power by Belting and Gearing.

It is stated by Flather that in shops using heavy Tools, the percentage required to drive the machinery will average from 40% to 50% of the total power expended;—this involves the inclusion of elevators, fans, and blowers.

In shops using lighter machinery and having a connected foundry the power percentage will be about the same, but without the foundry the expenditure of power in transmission will fall between the figures of 30% and 40%.

The elements of loss are—1st., belts running on loose pulleys; 2nd, numerous clutches; 3rd, numerous countershafts; 4th, points of flexure; 5th, inadequate lubrication.

The American machinist, Babcock, states that for ordinary work one H.P. is sufficient to drive machine tools necessary to keep ten men well employed. In two instances, quoted by Flather, one (Brown and Sharp Manufacturing Company) employ 3·91 per H.P., the other (Pratt and Whitney) employ 6·04 per H.P. Both firms turn out the same class of work. In one instance (the Baldwin Locomotive Works) the power absorbed is 80%. Henthorne considers, however, that shaft absorption should not exceed 19% of the initial power.

In the New England Cotton Mills the shaft power absorption is said to vary from 18% to 25%; so that with electric transmission we have, in the examples given, a possible margin of saving varying from 16% to 75%.

THE LAUFFEN-FRANKFORT TRANSMISSION OF ELECTRIC ENERGY (112 Miles).

DESIGNED BY HERR VON DOLIVO DOBROWOLSKY.

HERR PROFESSOR WEBER'S RESULTS.

Received from the Maschinen-Fabriken Co., Oerlikon.

Date. 1891.	Turbine H.P.	Efficiency Electric Generator (Dynamo).	Actual Working Efficiency.	The Actual Efficiency H.P. Step-up Transformers.	Working Efficiency	Loss of Conductor H.P.	Second Transformer Step-down H.P.	Nett Efficiency Second Transformer Step-down H.P.	Commercial Working Efficiency.	Nett efficiency Electric Generating Plant between poles of Dynamos or Electric Generators.	Total Percentage efficiency between Turbine Shaft and Consumer Terminals.	State of Weather.
11th October ..	120·9	108·1	0·894	102·4	0·947	7·3	95·1	89·5	0·941	82·6	74·0	Fine and dry weather.
,, ,, ..	121·1	108·3	0·894	102·6	0·947	7·6	95·0	89·4	0·941	82·4	73·8	
12th ,, ..	127·0	114·4	0·900	108·7	0·950	8·0	100·7	95·7	0·944	83·0	74·9	Dull.
,, ,, ..	127·5	114·8	0·900	109·0	0·950	8·1	100·9	95·8	0·944	82·9	74·8	
,, ,, ..	99·3	86·8	0·874	81·5	0·939	5·0	76·5	71·4	0·933	82·4	71·9	
13th ,, ..	105·9	93·3	0·881	87·7	0·940	6·0	81·7	76·3	0·934	81·6	72·1	Rain.
,, ,, ..	105·9	93·3	0·881	87·7	0·940	5·9	81·8	76·4	0·934	81·7	72·2	
,, ,, ..	151·8	139·1	0·916	132·8	0·955	12·8	120·0	114·0	0·950	81·8	75·1	
14th ,, ..	151·7	139·0	0·916	132·7	0·961	12·5	120·2	114·2	0·950	82·0	75·3	
,, ,, ..	194·7	182·2	0·935	175·1	0·961	24·4	150·7	144·2	0·957	79·1	74·1	
,, ,, ..	197·4	184·8	0·935	177·6	0·961	25·2	152·4	145·8	0·957	78·8	73·9	Fine.
,, ,, ..	117·6	104·9	0·892	99·2	0·946	7·5	91·7	86·2	0·940	82·0	73·3	
,, ,, ..	112·7	100·1	0·888	94·5	0·944	6·9	87·6	82·2	0·938	81·9	72·9	
,, ,, ..	78·2	66·1	0·845	61·1	0·925	3·1	58·0	53·5	0·922	80·9	68·5	
15th ,, ..	190·7	177·9	0·933	170·8	0·960	25·5	145·3	138·9	0·956	77·8	72·8	
,, ,, ..	190·0	177·3	0·933	170·2	0·960	24·9	145·3	138·9	0·956	78·1	73·1	Rain early in the day.
,, ,, ..	189·7	177·0	0·933	169·9	0·960	24·6	145·3	138·9	0·956	78·1	73·2	

TABLE showing the Fluctuations in the Price of Copper in the Ten Years ending 1892.

	1883.			1884.			1885.			1886.			1887.			1888.			1889.			1890.			1891.			1892.		
January	65	0	0	56	10	0	47	15	0	40	0	0	38	17	6	77	2	6	77	10	0	48	17	6	52	12	6	44	12	6
February....	65	0	0	55	7	6	47	5	0	41	0	0	39	7	6	78	17	6	78	0	0	47	0	0	52	15	0	44	5	0
March	64	15	0	53	17	6	45	5	0	41	10	0	39	10	0	80	2	6	39	5	0	47	12	6	53	2	6	46	5	0
April	62	17	6	56	10	0	43	5	0	41	7	6	39	7	6	80	2	6	37	15	0	49	2	6	51	12	6	45	12	6
May.....	63	15	0	56	0	0	45	2	6	39	10	0	39	5	0	80	15	0	41	0	0	54	10	0	55	5	0	46	7	6
June	64	0	0	54	2	6	44	10	0	39	12	6	40	0	0	81	0	0	41	10	0	58	10	0	55	5	0	44	17	6
July.....	63	12	6	55	0	0	43	10	0	38	17	6	40	0	0	80	10	0	42	0	0	57	0	0	52	0	0	44	17	6
August.....	64	0	0	53	17	6	42	7	6	39	7	6	40	2	6	89	0	0	43	10	0	60	5	0	52	10	0	44	7	6
September ..	63	0	0	54	2	6	40	15	0	41	2	6	39	15	0	100	0	0	43	0	0	59	10	0	51	2	6	44	2	6
October	61	5	0	52	12	6	39	10	0	40	7	6	44	5	0	78	5	0	44	2	6	58	7	6	46	5	0			
November ..	59	10	0	51	5	0	42	7	6	39	15	0	66	15	0	77	10	0	50	2	6	55	7	6	44	12	6			
December ..	58	0	0	47	5	0	41	0	0	38	10	0	85	0	0	77	10	0	50	2	6	52	10	0	46	15	0			

Prepared for the author by Messrs. H. R. MERTON & Co., 2, Metal Exchange Buildings, Leadenhall Avenue, London.

DISCUSSION.

The discussion on the foregoing paper took place on Saturday, the 26th November, the chair being occupied by Mr. T. Ashbury, C.E., Past-President. The Chairman opened the proceedings by calling upon Mr. Thwaite to make a few remarks which he said might lead to a discussion of the paper.

Mr. THWAITE said that to many of those present his proposals with regard to the generation of electro-motive force would doubtless appear to be in advance of the times; but he would remind them that every great scheme required an initiation, and he did not think Manchester would be dishonoured by becoming the birthplace of the propagation of this scheme. How many great undertakings, such as the Lauffen-Frankfort one, for which the wiseacres had prognosticated dismal failure, had proved the greatest successes? The whole technical and scientific world was indebted to the German government for fixing and determining the long-distance efficiency factor of high pressure transmission, as this would have more effect in supplying natural force for the well-being of man than any other of the creative human efforts of the last century. The Bradford Corporation Electric Lighting Committee had already commenced to distribute power to the ratepayers for industrial purposes, and, although it might be years hence ere the power-distributing system in its entirety would come into play, that it would come, was as certain as that daylight followed night. While it was placing in the hands of our industrial competitors potent weapons which might prove damaging to us in our fight for industrial existence, in our hands it could be made a power for our country's good.

THE CHAIRMAN (Mr. T. Ashbury), said:—The best thanks of the Association were due to Mr. Thwaite for the able and important paper he had prepared and read before them on the great prospective possibilities in the generation of electro-motive force, and which he had so profusely illustrated by diagrams,

etc., also for the "Electrolytic" manner with which he had endeavoured to inflame and to infuse into his hearers his own intense burning zeal and enthusiasm for the glory of his favourite goddess, Electra, whose beauty and prowess he had so highly extolled, and whose star was now so prominently in the ascendant. The subject introduced by the author was one which demanded their careful attention, though he admitted that it was impossible to analyse and discuss the paper in the short time at their disposal. During the past few years such great advances had been made in the application of electricity, that they would hardly venture to say the most visionary schemes brought before them in this direction were impossible. The author had given credit to Manchester as being the cradle of many engineering developments, and he had introduced two names, Joule and Wilde, as great men in that respect. Joule of course was well known, but Wilde demanded a passing note of reference. To Wilde the honour was due of developing the dynamo in a way and giving it a start from which it had never retrogressed. It was the speaker's pleasure to be associated with Mr. Wilde in producing the first electric-search light which was put on any vessel, he being deputed to test, examine, and report on the dynamo which was made at Mr. Wilde's works. The light was ultimately fixed on a steam vessel in the Thames, and subsequently four similar lights were ordered by the Lords of the Admirality for men-of-war. Therefore to Manchester, he thought belonged the credit of putting the first electric search-light on an English vessel. Reference had been made by the author to Switzerland and the production of aluminium in that country; and in regard to this he might say that recently, when in America, he was present in a room while two of the Directors of the Niagara Falls Power Co. were discussing with the President of an Aluminium Co. the terms for the supply of 5,000 horse power for the production of aluminium. It might be added also, that in this country aluminium would soon be produced, not by steam engine, but by water power. With regard to the supply sources suggested in the paper, he thought there were some disadvantages which could not be overlooked. Assuming that there were a thousand installations of engine power on the route indicated, if one source failed, then only one

out of a thousand failed; but if they had a thousand motors drawing from one central source, and that central source became stopped, then they had a thousand firms stopped simultaneously. Under these circumstances it appeared to him that the 7,000,000 of horse power which was represented in this country in steam engines and boilers would not be readily displaced by the new force. The Birmingham Corporation compressed air project (which he thought emanated from Liverpool) was supposed to be a grand scheme on its initiation, but in the paper was called "That ill-fated scheme," and might not the scheme proposed by the author possibly have a similar ending? Again, it seemed to him that whether engines were working intermittently or not, it was not fair to assume that those ten engines would only be working so many hours. If a central source of power were proposed at all, it was absolutely necessary that the maximum power required should be provided that would be requisite, in case all the engines were working at one and the same time. It would be a fatal and disastrous experiment to profess to supply power on the assumption and chance of all the engines not working simultaneously. He was certainly surprised to learn that three millions sterling was invested by the Metropolitan Companies in electric lighting. The bold ideal scheme set forth by the author, might be thought by some Utopian, but, nevertheless was worthy of consideration. So they must not condemn too hastily. Longfellow's inspiriting lines say:

"Let us then be up and doing
"With a heart for any fate,
"Still achieving, still pursuing
"Learn to labour, *and to wait.*"

and possibly the latter would be very much in requisition before they saw Mr. Thwaite's proposal an accomplished fact.

Mr. A. G. Brown remarked that the paper was somewhat voluminous and in some instances seemed to be of great value. If a company were going to be formed for the purpose of carrying out the scheme, the paper would be of considerable value to the projectors, but otherwise he failed to see its

application. As regards the advantages of central power generating stations, he thought the author had not in any way too strongly urged their adoption. In several establishments where they had replaced their engines by electric motors, an immense saving had taken place, and he believed he was not far wrong in asserting that taking an ordinary machine works, where several engines were required, at least 50% of the power would be saved by having a central generating station supplying electricity to motors in various parts of the works. The cost of such an installation would however be rather heavy, and for that reason in many cases it would not be adopted. Passing over those remarks in the paper with which he agreed, he came to those in reference to the motive power for electrical installations. Naturally, a gas engineer would prefer gas engines, but, on the contrary, a steam engine manufacturer would be able to show up the disadvantages of gas plant. These disadvantages were not so clearly shown in the paper as might be desirable, but without further reference to that feature, he did not believe any electrical station could be run economically without storage cells. In that case he did not think a steam engine would have the disadvantages referred to, namely, quoting from the author: "Where the source of power is the natural waterfall, it is, of "course, unimportant if the load is suddenly taken off, but with "a steam engine plant the sudden stoppage of the engines "throws the whole of the generated steam back on the boilers, "involving a sudden rise of steam pressure." Of course the sudden stoppage of an engine would cause a loss and slight rise in pressure, because the steam would not leave the boiler, but in such a case the dampers would be attended to and the loss would be comparatively small. Excessive demands were sometimes made on the motive power in electrical stations, and these demands could only be met promptly by storage cells. He thought that gas engines were far less reliable than steam engines, and, consequently, in many cases the former had been displaced or superseded by the latter. He could not agree with the singular theory propounded by the author in reference to the atmosphere of Manchester, and if the high-pressure or non-condensing engines in Manchester exhausted sufficient cylinder oil to permeate the atmosphere, as implied in the paper, the oil

trade here must be pretty good. As to the hygienic economy of the electric light he thought its superiority could not be questioned. The cost of running the 10,000 horse power generating station as indicated, seemed to him a most astonishing and marvellously economical calculation, and one which he fancied would not leave margin enough for sufficient cylinder oil to injure the atmosphere in its vicinity, and he would like to know on what basis it was arrived at.

Mr. Alfred Saxon observed that one of those questions which they as practical engineers had to face with regard to the author's proposal was, whether they would have as steady running in their textile factories by driving with electric motors—either of sufficient power to drive the whole of their machinery or separate motors perhaps for each room or storey—as with the large engines now in use; his own opinion was that they would not. As regards the waste of fuel due to early lighting it should be borne in mind that steam was not simply used for driving the mills but was largely used for heating purposes. He thoroughly agreed with the author as to the advantage which would be gained in comparison with small engines. With regard to the cost of the installation, he thought that the author had underestimated it considerably. Although he firmly believed the development of electricity to be one of the things on which they had to rely for assistance in their industrial competition, he considered the author's scheme was in every way too costly to entertain at the present time. For several years past firms with whom his firm had business relations, had been utilising their surplus engine power in the driving of dynamos for the electric lighting of their mills and manufactories, and at the present time the directors of one of the new mills being built in the neighbourhood of Oldham, (for which his firm were making the engines), had decided to have it lighted by electricity. The dynamo was to be driven by the main steam engines. By adopting electricity in such a way, it enabled them to fully utilise the present method of driving, which method was so serviceable in other respects, as previously mentioned, and at the same time they were receiving the benefits which the electric light conferred, cheaper than an electric plant driven by a gas

engine, and cheaper than lighting the mill by gas in the ordinary way. A gradual adoption of electricity he was prepared to recommend and endorse, but he could not go the lengths proposed by the author of the paper.

Mr. E. G. CONSTANTINE was of opinion that the author had submitted a paper well worthy of their serious consideration. Mr. Thwaite had initiated a scheme which, although in its entirety might never be carried out, would in future years probably be the basis for developments in the adoption of central generating electrical stations.

As regards the pollution of the atmosphere, he had no hesitation in thinking that it was due rather to the domestic chimneys than to the smoke emanating from manufactories.

He did not think Mr. Saxon need trouble himself about the heating of factories in case of the general adoption of central electrical generating stations, as he did not doubt the originators of that system would be prepared to meet that difficulty. He had personally great pleasure in expressing his thanks to the author for his valuable paper, and the very able manner in which it had been submitted to the Association.

Mr. J. BARTLAM said that four years ago an installation was put down at Portwood Mills, Stockport. At that time they found they had sufficient surplus engine power to turn a dynamo, and the installation, by their own calculations and tests, showed that a clear saving of 10 to 12 per cent. had accrued as compared with gas.

To put down special engines for driving the dynamos was of course expedient, but when there happened to be a margin of engine power and the turning from same was good, its application for electric lighting would be advantageous in many respects, both to the employer and the employed.

If, in addition to the cost of the installation of dynamo, wire, etc., the cost of the proportion of engine and boiler power required to turn the dynamos was added, it would mean an additional cost of £150 which at 5% depreciation and 5% interest on capital invested, would bring it to about the same

as gas. But they had a better and brighter light than they would have with the same equal number of gas lights from either No. 4 or 5 Bray's burners.

Mr. J. H. Beastow remarked that, undoubtedly where there was a steam engine and boiler in existence, electric lighting was far more efficient and less costly than gas. He intended trying an experiment of driving the tools in various parts of the works from the same dynamo which was creating the electric light. He thought it would be more economical than carrying steam pipes through the works, as in case of a breakdown it only took a few minutes for re-adjustment. With the author, he thought that in a few years the steam engine, especially for small powers, would be obsolete. He believed that if the great steam engine makers would tackle the problem of making gas engines of greater power than at present, it would be beneficial in every way to the country at large.

The Chairman (Mr. T. Ashbury) then again gave expression to the indebtedness under which they were placed to Mr. Thwaite for the industry and thought he had expended on the preparation of his paper. It would stand their serious consideration he said, and they would no doubt look back to it in future years with increased interest, as he thought considerable light would be thrown in time on the paper they had heard a fortnight ago; and he was sure they all appreciated the good will which Mr. Thwaite had shown to their Association. He therefore moved "That the best thanks of the members be accorded to "Mr. B. H. Thwaite for the very able, efficient and exhaustive "paper he had submitted for their consideration."

The motion was carried with acclamation.

Mr. Thwaite said he sincerely thanked them for their kind appreciation of his efforts. He would like them to understand that it was against his grain to go in opposition to any established method of procedure in engineering. His aim was simply to give them an insight into the light of the future, and to ask them to master the elements of electric generation, as he

did not see why any Manchester engineer should fear to face the question. He could not do justice to their remarks that evening, and he would, with their permission, answer them by correspondence.

The author subsequently communicated the following reply :— The interesting incident relating to the introduction of the Electric Search Light is very welcome. Since the initiation of the system as described by Mr. Ashbury there has been a great development of the application of this electric arc search light. It is nightly employed on the Suez Canal for guiding the Oriental and homeward-bound steamers through the numerous windings of Lesseps' creation—a name that, despite the present shadow surrounding it, should before Engineers *ever be mentioned with respect.* Nearly all the first-class British and Foreign armourclads are equipped with this search-light—a fitting sentry in its searching power,—to watch that insidious and destructive assailant, the torpedo, the invention of another Lancashire man.

It will be the greatest return to the author for the trouble involved in the preparation of this paper if Wilde's name, referred to in the chronology and genesis of electric power transmission development, obtains that recognition in the electrical world of science which it deserves.

Referring to the aluminium production, the remarkable development in the weight and the reduction of cost of production in Switzerland of this, the coming metal, is due to the great facilities for obtaining dynamic energy that the Alpine regions provide. There is no doubt but that the general distribution of low priced units of electro-motive force would open up centres for the manufacture of aluminium, either by the Hall, the Bernard-Minet, the Heroult, or some other Electric Process.

The objection raised by Mr. Ashbury to the possibility of failure of supply from a central source, might be argued with as much force against a central gas or water supply installation. Supposing the water source conduit leading the water from Thirlmere was to burst, what would happen? And again, assuming the Beckton Gas Works to be blown into space, the light of thousands of cottages would be extinguished. This

is the argument of timidity against all centralisation projects, and carries with it its own condemnation. It is worthy of the old coach days and the days of lantern lights and tallow candles, and of the innumerable pumps and water wells.

Mr. Ashbury's objection to the proposal to merely work the plant to the load required to meet running demands (it must be understood here that it is intended to work the engines invariably at the full load,) is a solid one, but if Mr. Ashbury will kindly look through the details of the project, his objections will then I think be dissipated. Here is an illustration of the actual effect of carrying out the proposed schemes of electro-motive force distribution. The author is presumably a power using subscriber; he requires power, and therefore switches it on; this action automatically records itself at the Central Generating Station, because the pressure on the mains is always kept at the maximum, and an additional absorption of power would reduce this pressure if it was not followed up at once at the Central Station. When the degree of absorption of power reaches the maximum output, another gas engine is automatically started, and when the gas holder falls to a certain level by the removal of its contained gas this puts in action a relay magnet contrivance that turns on extra steam at the generator and increases the speed of the automatic fuel feeding gear; the same automatic action actuates the speed regulating gear of the exhausters. The remaining part of the plant is unaffected.

The gas holder represents the potential of thermo-dynamic energy, and a supply can be obtained in a mere fraction of time. The *storage of gas involves no loss*, even if the time of storage is one or many months, and the cost of storage is merely the cost involved as interest on the capital outlay expenditure in the building of the holder and painting it. The storage of fuel gas does not carry, as an incident, the same loss that does the storage of retort gas. This latter gas loses by prolonged storage, part of its hydro-carbon constituents and has consequently reduced photometric value, whereas the fuel gas will not suffer any appreciable thermo-dynamic loss.

Respecting the reference to the Birmingham Air Power Scheme mentioned by Mr. Ashbury, there is absolutely no direct or correlating relationship between the system of electric long-

distance-power-transmission, and that in which air is the agent employed. The former is in operation in many hundreds of instances, giving every satisfaction, whereas the air power distribution was bad in initial conception, imperfect in creation and inefficiently carried out. The Chairman of the Company admitted to the author that the fuel consumption involved in the compression of the air was twice what it should have been, and it is a notorious fact that the mains would not permit the intended pressure to be continuously sustained; add this to the imperfect features of the conception, and the explanation of the result of this enterprise is sufficiently well told.

No arguments, theoretic or practical, can be raised against the author's and Mr. Swinburne's projects as far as they relate to the actual delivery of the electro-motive force generated.

In reply to Mr. Ashbury's final remarks, projects of the kind suggested, and of national importance, have often to wait long years before the time of their actual execution arrives; but once their creation is effected, the project may prove beneficial for all time.

The author thanks Mr. A. G. Brown for urging the advantages of Central Power Generating Stations, and for his confirmation of the immense saving in power to be derived by discarding shafting, belting, and other usual means of power transmission, and employing instead direct coupled electric motors for the transmission of the energy. The initial cost of establishing such an installation will be somewhat higher, as Mr. Brown shews, although a reference to the table of relative costs (*vide* Appendix) of identical power of gas, steam, and electric motors proves that when the cost of the long line of turned shafting, pedestals, gearing, pulleys, and belting is deducted, the additional first cost is not great; but, compared with the reduced cost in fuel, in lubricants, in renewal of belting, &c., when such saving is capitalised the extra cost is splendidly justified on economic grounds.

Mr. Brown introduces the gas and steam engine question into his remarks. This is a subject that is well worthy of the consideration of the Manchester Engineeers' Association, and would serve as an admirable topic for discussion.

The author has already presented his reasons for giving his preference for the gas engine.

Mr. Brown urges the necessity of storage cells, but on further examination of the author's paper he will observe that for the Central Station, the *gasholder will displace the necessity of storage cells.*

The storage batteries will, however, enable the central generating plant to be run night and day. During the night-time certain consumers requiring the most absolute regularity of potential could have their electric power storage batteries charged, and the night current would also be utilised for charging, by the intermediary of a continuous current machine, the storage cells of some of the London Electric Lighting Companies. By this means the electro-motive power plant at the generating station could be kept working at full load during the night.

But at the central station the gas holder will serve the purpose of storage batteries, and with the conspicuous advantages already set forth.

The method of driving the alternators proposed by the author and Mr. James Swinburne, that is, rotating the fields and alternators in opposite directions, would overcome some of the difficulties originally experienced with gas engines; but with the later types of these engines, electric-generating machinery is being driven with every satisfaction, whether working with ordinary town or cheap fuel gas.

It is to be regretted that Mr. Brown does not accept the author's theory to explain the greasy and high rainfall phenomena of the Manchester atmosphere. As Mr. Brown has been a resident of Pittsburg, Pa., he will readily admit the metamorphosis of the atmosphere that followed the displacement of imperfect methods of burning bituminous coals by natural fuel gas in that city.

The combustion of bituminous coals produces either water or tar, as part of the constituents, the latter in a finely divided condition, causing the smuts and smarting sensation when deposited on the face, and the greasy condition of the pavement. Taking the formula for the hydro-carbons of bituminous coals

to be represented by $C_2 H_4$, then the combustion will follow sequentially thus:—

$$(C_2 H_4) + (6N_4 O) = (2 CO_2) + (2H_2 O) + 24N.$$
$$(\text{Hydro-Carbon of bituminous coal}) + (\text{Atmospheric Air}) = (\text{Carbondi-oxide}) + (\text{Water-vapour}) + (\text{Nitro-gen})$$

We thus realise that water vapour is produced, and as the natural hygrometric condition of the Manchester atmosphere is rather high, the critical point of ultimate saturation is soon reached by the addition of the aqueous vapour resulting from the oxidation of the hydro-carbons as formulated, and from the introduction of steam; once the critical point of ultimate saturation is exceeded, the almost proverbial rainfall of Manchester follows.

Mr. Brown accepts the claimed hygienic superiority of the electric incandescent light over its rivals.

With reference to the cost of labour in working the Central Station Plant it must be noted that it does not include the cost of the labour involved in the Condensing and Sulphate of Ammonia Plant.

Seeing that the gas generators will be automatically fed, the only labour involved will be that required in the clinkering and shaking-up of the fuel. Two good gas stokers will control both the gas engines and gas plant, whilst two electricians with two assistants can control the electric generating and transforming plant. But even if the labour charges were doubled, this would hardly effect the cost of output, it would only add £100 a year per 1,000 B.H.P. produced for all the year round. Mr. Saxon makes a very pertinent and important enquiry in asking if the electric driving gear would run textile machinery as steadily as does the present system. A careful and unprejudiced consideration will shew that high pressure high alternating currents will produce a greater regularity of production of dynamic effort than can possibly be obtained by the reciprocating steam engine. Anyone who has examined Moscrop Recorder Cards knows this, and it is only with high-class Corliss or Sulzer type of engines that any approach to the ideal straight line of the Moscrop card can be obtained. Transforming down makes no difference. Electric-motors run more steadily than any other type of

machine known, except say, an astronomical clock with circular escapement.

Textile mills are being driven by electric motors that have displaced steam engines, and the author has never heard any complaints under the head of unsteadiness. A system that can produce such a steady flow of energy as to maintain the delicate carbon filament of the incandescent glow-lamp in a glow of incandescence with a variability *undetectable* by the sensitive retina of the human eye, can surely be trusted to drive textile machinery, even *for spinning the finest counts.*

Mr. Saxon draws attention to the proportion of fuel required for raising steam to warm the factories. This steam could, however, be much more economically generated by the high pressure system, such as that of Perkins; and it must be borne in mind that the steam requirement is a variable one, attaining its maximum in winter, and its minimum in summer, whereas the fuel power supply is a fixed quantity all the year through.

The proportion of fuel that need be required for warming and steaming purposes is small compared with that demanded for power purposes.

Mr. Saxon agrees with the author in his statement of the advantages of large steam engines compared with small ones.

The cost of running copper wires compared with the cost of steam pipes, shafting, or heavy gearing, is much in favour of the former, and a breakdown can be repaired in a few minutes; whereas a breakdown of shaft or gearing, or burst steam-pipe, may cause loss of property, capital, and even life, besides involving a more or less serious stoppage of the works.

Mr. Saxon considers the cost of the scheme rather large. If he will carefully examine the cost of production of power, taking into his survey the account of the advantages of centralisation, he will realise that, compared with the cost of a horse-power per week, taken at say 7d., for the best practice with steam driving gear in Lancashire, that the cost of this equivalent power, if the author's scheme is carried out in its entirety, will for Lancashire and Yorkshire not exceed 3½d., allowing for the fuel to raise steam for warming, sizing, &c. But if the power were delivered even at the same cost, the advantages of greater

security, no anxiety for the safety of the steam boiler, no trouble *re* supply of coals—the alteration is well justified, and the lot of the mill and factory owner, compared with that of the present system, would indeed be a happy one.

Mr. Constantine clinches the argument respecting the warming of the factories, and he is quite right in suggesting that this objection would be quite easily met.

Mr. Saxon interpolates an interesting fact that he had found many factory owners were already utilising the surplus power of the mill engines to drive electric light generating plant.

Mr. Beastow emphasises an important fact in that it would be more economical to lead copper wires through a works than steam pipes, because in the event of a breakdown it only requires a few minutes to effect a readjustment. Mr. Beastow also coincides with the author in the suggestion that small steam engines would become in a short time obsolete. The author, however, considers that the modern high-class mill and marine engine will for many years to come have an exclusive field of fitness.

Mr. Beastow suggests, and the author is thoroughly in accord with him, that the great steam engine builders should, like Tangye's and Greenwood & Batley's and others have done, tackle the problem of making large power gas engines. The saving of 10 to 12% obtained by putting down a dynamo, and using the excess engine power stated by Mr. Bartlam, is evidence of the economy of the system applied to lighting.

Finally the author thanks Mr. Ashbury for his remarks in closing the discussion, and also tenders his gratitude to the members of the Manchester Association for their patience and for their expressions of good-will, which he heartily reciprocates.

Mr. James Swinbourne, in a communication, wrote:—

Mr. Thwaite has covered the ground so completely that I have but little to add. Central power stations must come, the only question is, When? I do not think storage batteries should be used in connection with such a system as that proposed.

They would save some of the capital sunk in gas engines, and would reduce the loss in the leads if placed in London, but they would involve losses of power, and capital, and maintenance, expenditure which would more than counterbalance their advantages. The energy can be conveniently stored as fuel without waste, so there is no need to store, in an intermediate form; it had better be delivered direct as wanted.

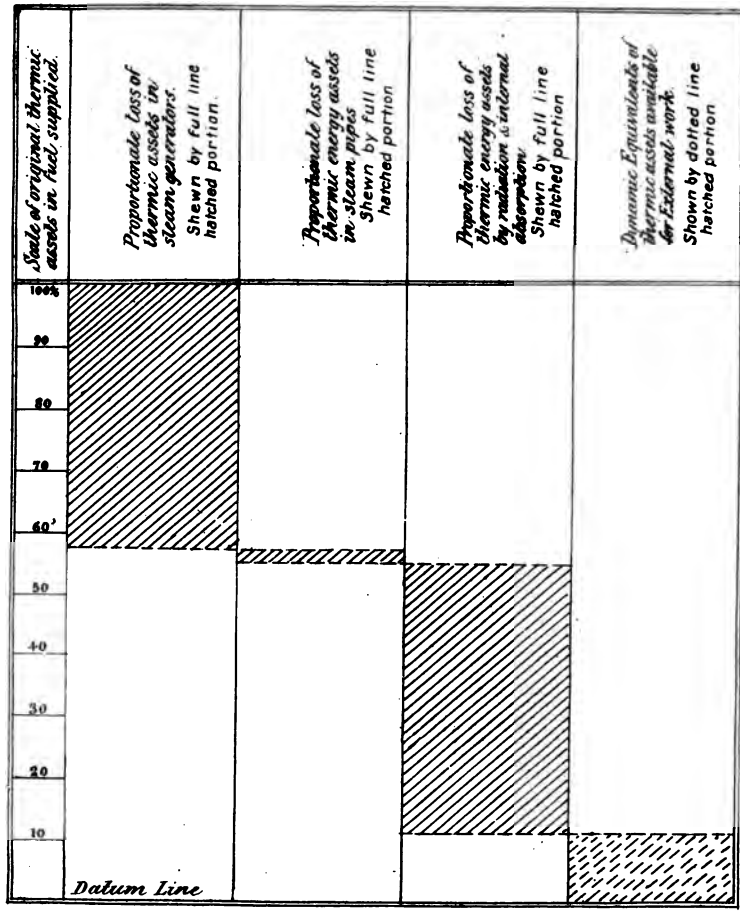
The virtues of electric motors do not seem to be appreciated by engineers. They are very efficient, waste almost no power when running idle, and they have a remarkable property of uniform speed. Even if the engine driving the generator varies in speed, so that the electrical pressure varies, a shunt motor runs at constant speed.

In making comparisons it must be remembered that a factory driven by, say, a 100 h.p. engine, does not need 100 h.p. to drive it electrically. If much shafting is used, the machines may only have a maximum of 20 or 30 h.p,, but even when they are all idle the engine develops a large portion of its full load. If motors are used, the maximum power needed is only 20 or 30 h.p., and varies down to nothing, as there is no consumption whatever when the motors are out of circuit. As soon as electric motors are familiar to engineers and millwrights, belting, pulleys and shafting will disappear. It is only a matter of time.

Plate 1

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

APPROXIMATIVE DIAGRAM, showing the allocation of the thermic assets in thermo-dynamic conversion, by the Steam Engine Plant.

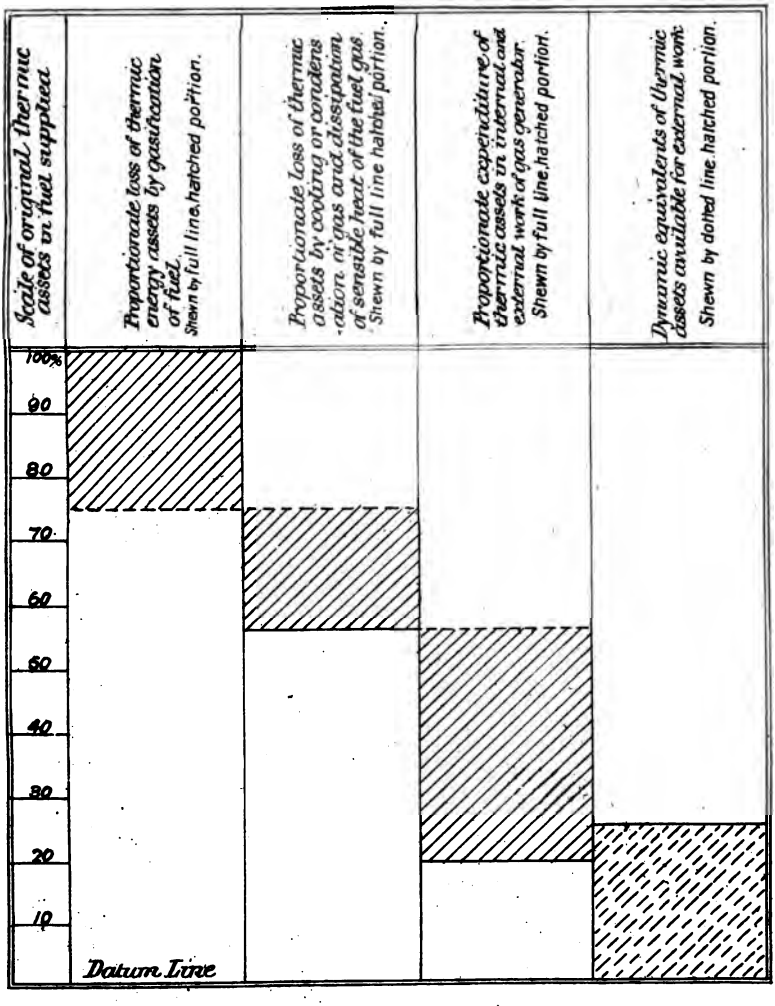


B.H. Thwaite, C.E.

UNIV. OF MICH.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS

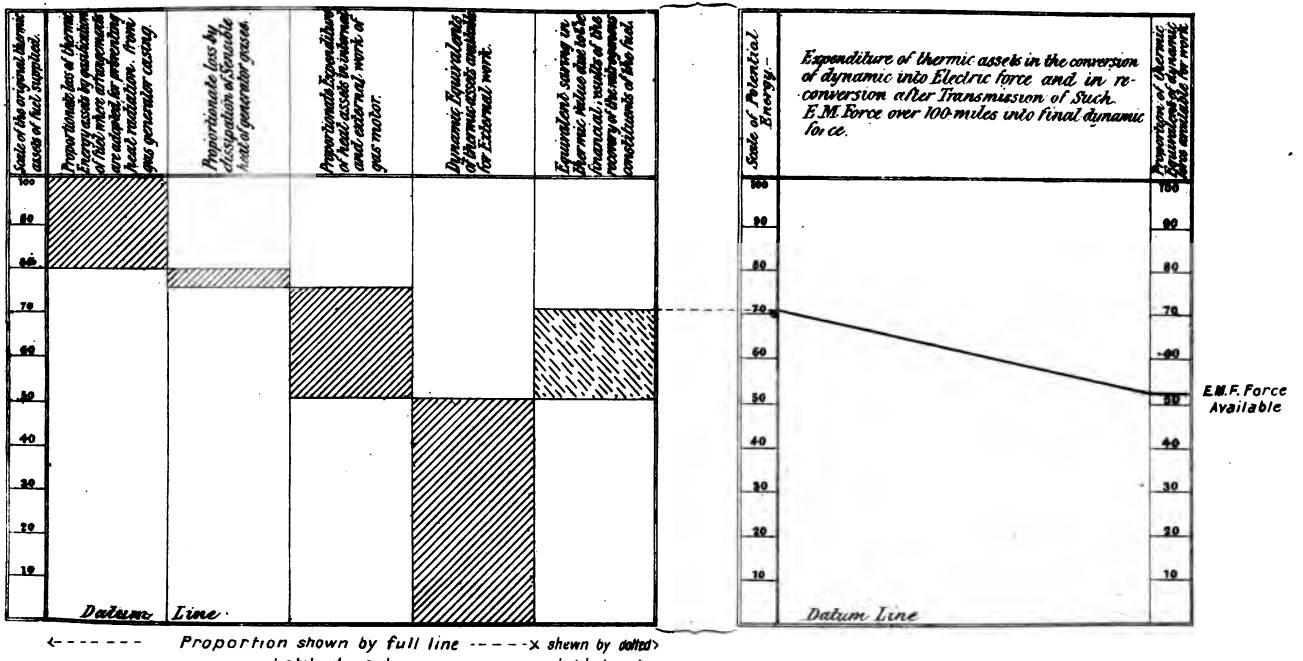
APPROXIMATIVE DIAGRAM, showing the allocation of the thermic assets in thermo-dynamic conversion by the Gas Engine Plant.



B. H. Thwaite, C.E.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS

GRAPHIC APPROXIMATE DIAGRAMS showing the possible practicable thermo-dynamic efficiency of a large gas engine plant driven with fuel gas, and with arrangements for the recovery of the nitrogen, and the transmutation and transmission of the net available energy by efficient electric generators, electric conductors and transformers, at distances of 100 miles from source of initial production of dynamic energy.



ESTER ASSOCIATION OF ENGINEERS.

B. H. Thwaite, C.E.

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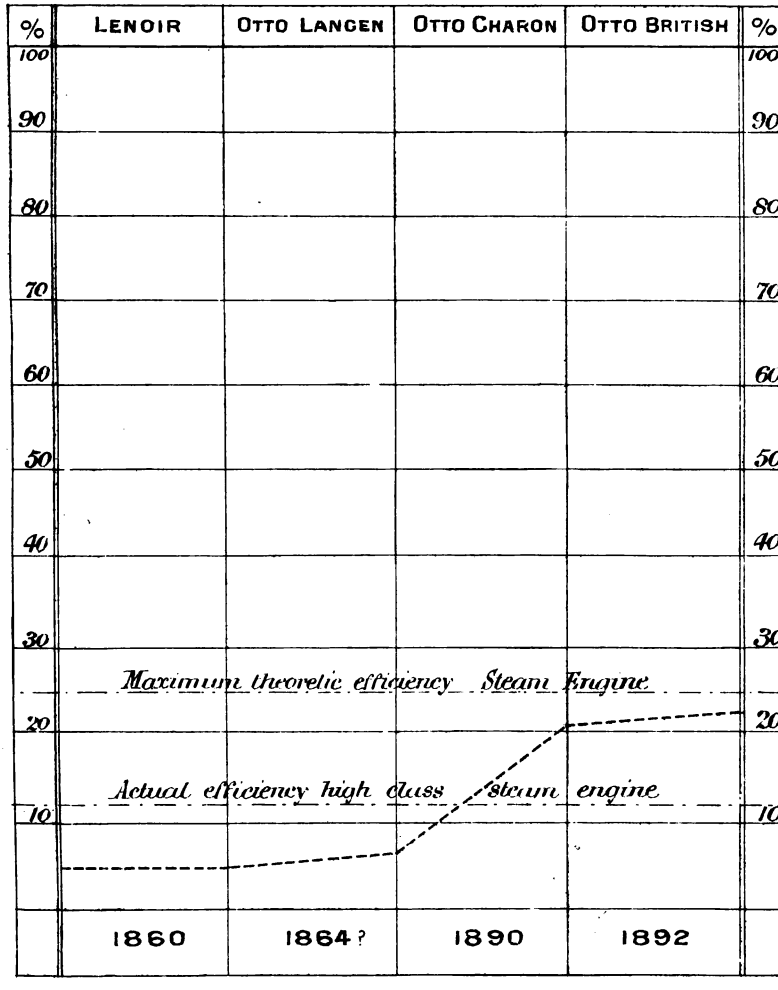
ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing the Thermo Dynamic Efficiency in percentages of the Theoretic Maximum of Epoch making Gas Motors.



B.H. Thwaite, C.E.

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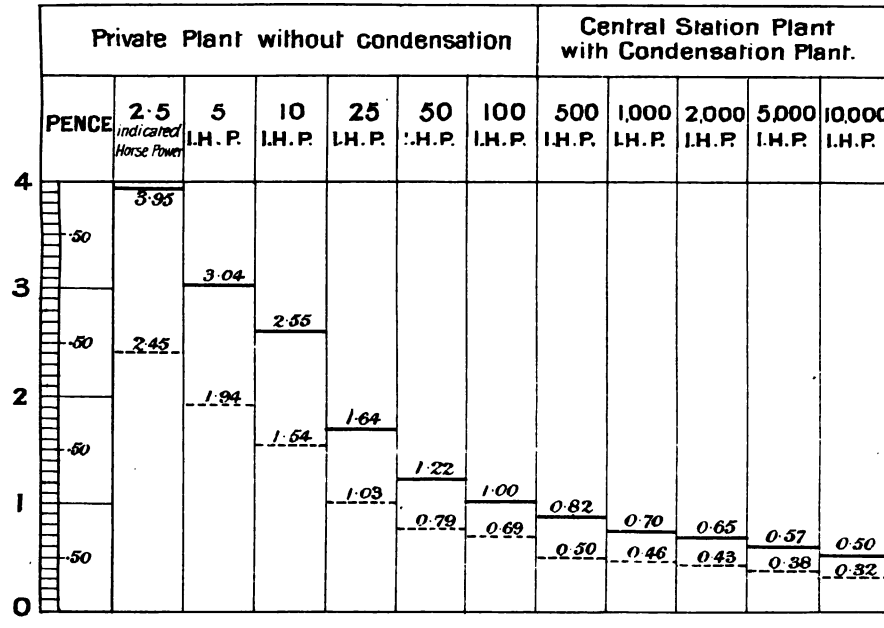
OF
MICH

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing reduced cost per I.H.P. per hour in large installations of steam engines compared with smaller installations. Based on Prof. Salomon's figures. Coal at 14/- per ton.



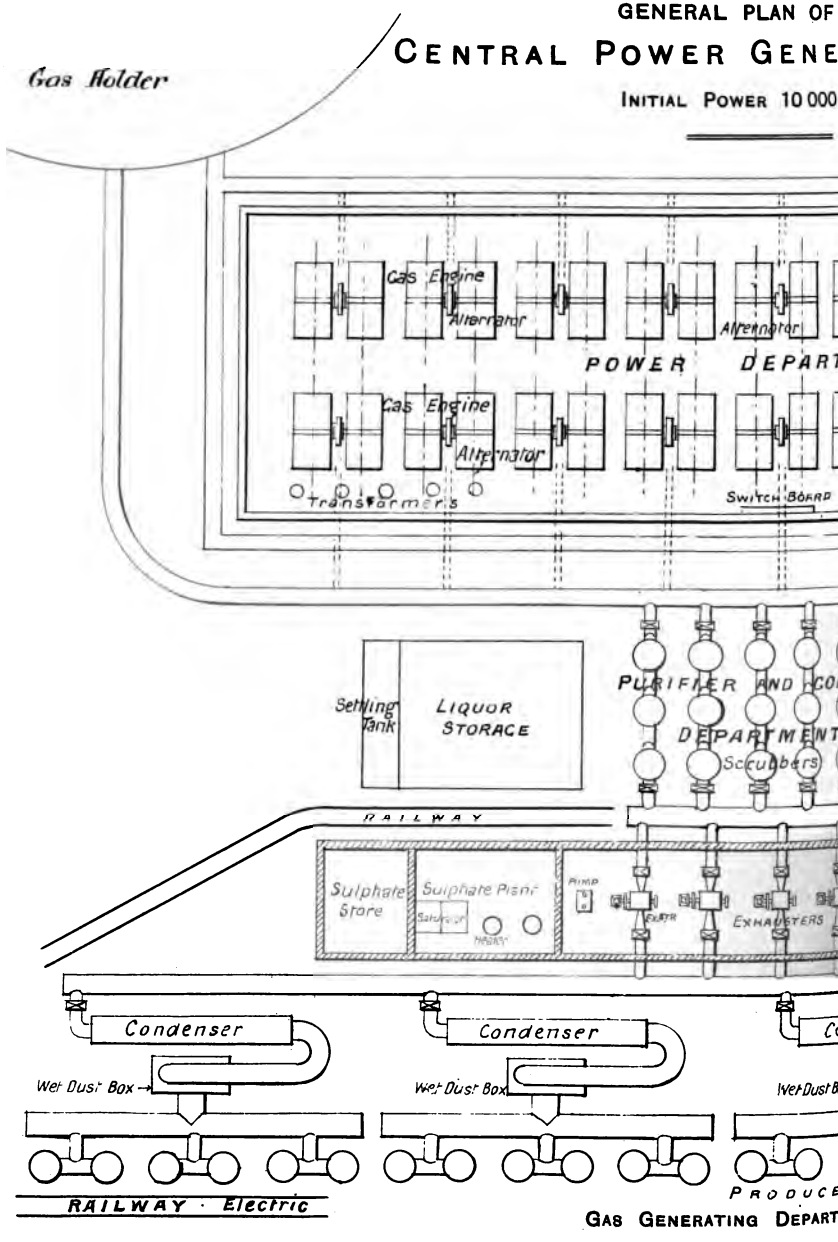
NOTE.—Full line shows cost in pence per I.H.P. per hour, working 1000 hours per annum. Dotted line shows cost in pence per I.H.P. per hour, working 3000 hours per annum.

ELECTRIC POWER TRANSMISSIO

GENERAL PLAN OF T

CENTRAL POWER GENER

INITIAL POWER 10 000

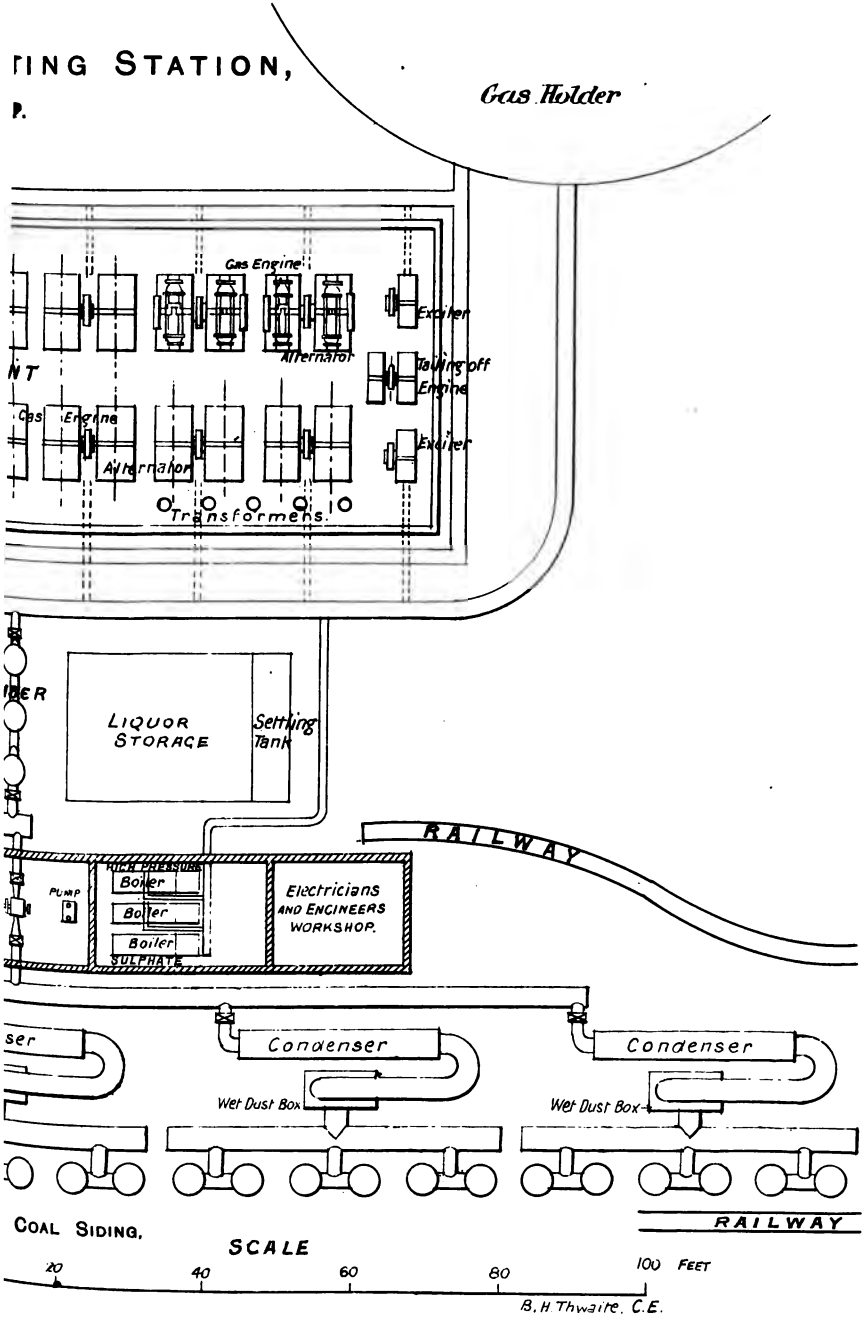


10,000 H.P. PLANT.

FROM COAL FIELDS.

TING STATION,

P.



B. H. Thwaite, C.E.

UNIVERSITY OF MICHIGAN

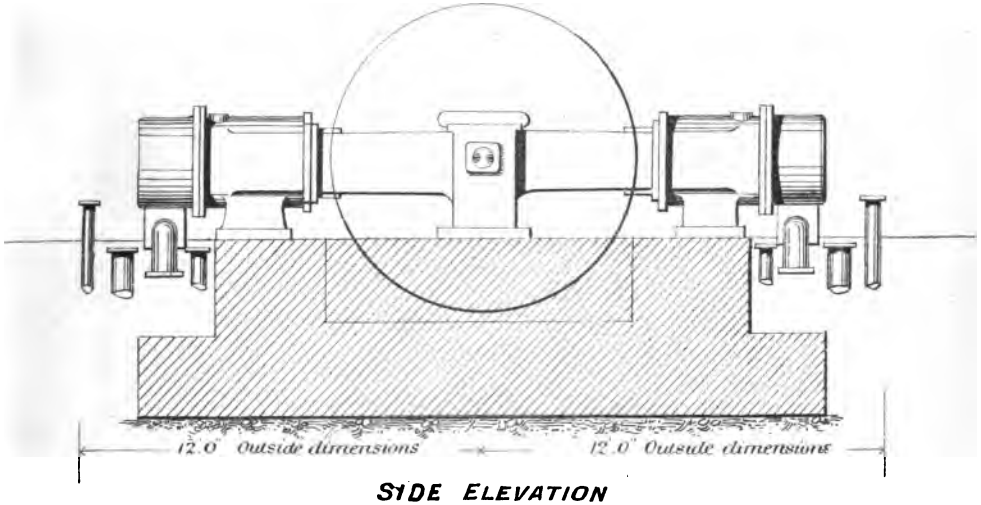
ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

ONE TYPE OF ECONOMIC "THERMO-DYNAMIC" MOTOR.

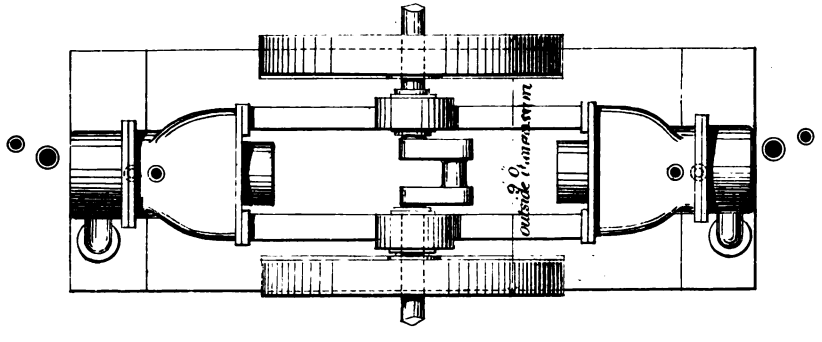
ESTIMATED CONSUMPTION OF FUEL—¾ LB. SLACK COAL OR ANTHRACITE PER INDICATED HORSE POWER.

300 BRAKE HORSE POWER GAS ENGINE.

OTTO CYCLE. USING GENERATOR FUEL GAS



SIDE ELEVATION



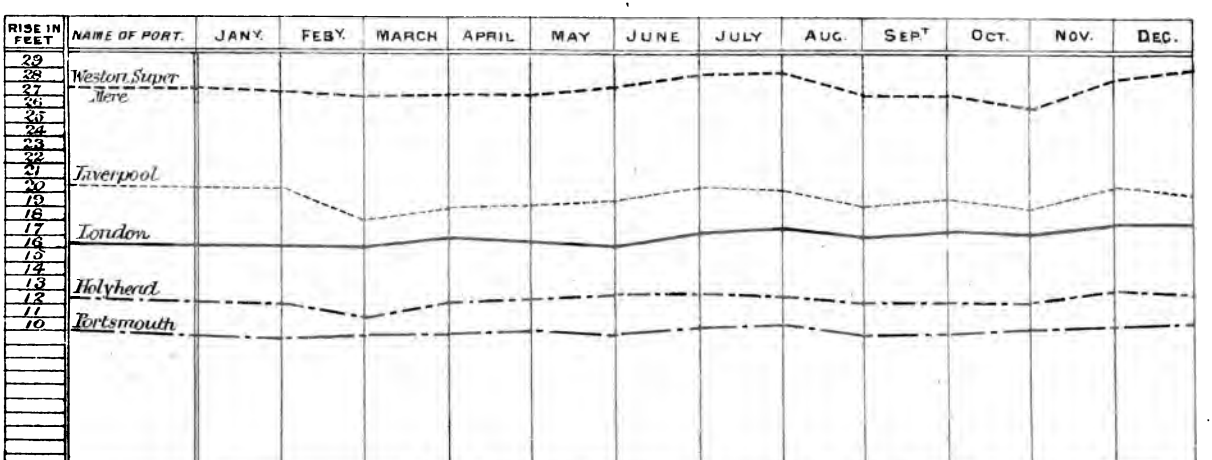
PLAN

Type of Crossley Brothers Ltd Latest Practise.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing Tidal Flow at some British seaports where the minimum difference of tides in any month exceeds ten feet.

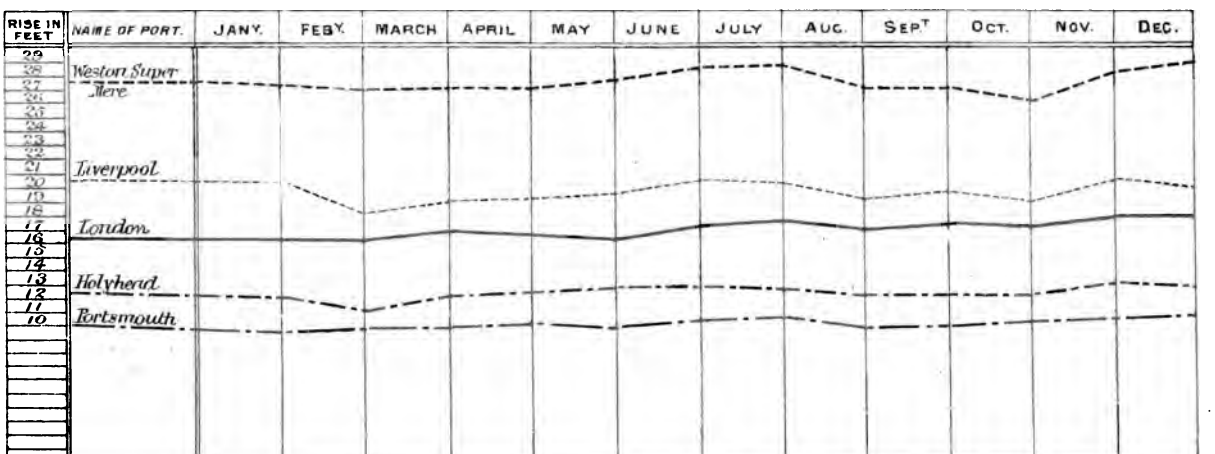
Based on Government Hydrographic Tables for 1892.



ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing Tidal Flow at some British seaports where the minimum difference of tides in any month exceeds ten feet.

Based on Government Hydrographic Tables for 1892.



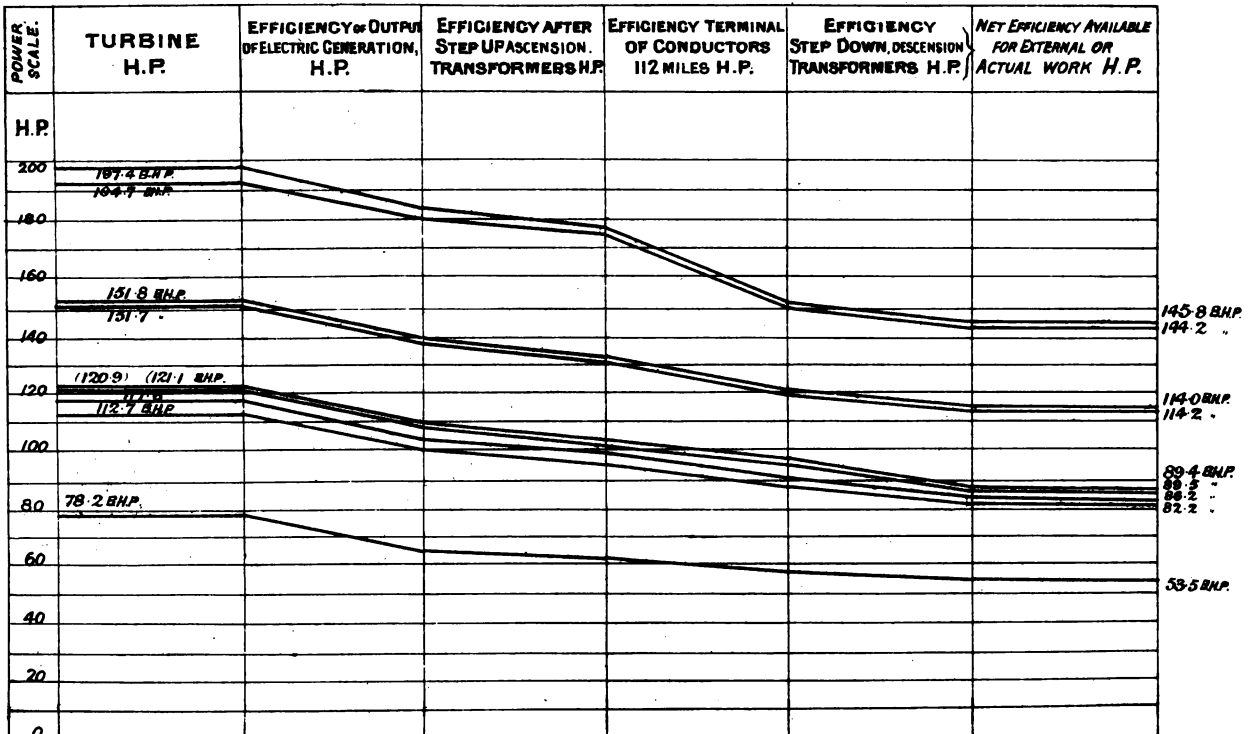
UNIV. OF MICH.

Plate 9

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

FINE DAYS.

DIAGRAM showing the absorption of energy by the elements constituting the Lauffen, Frankfort Line of Power Transmission (112 miles), indicating the net energy available. Prepared from the official report by B. H. Thwaite.



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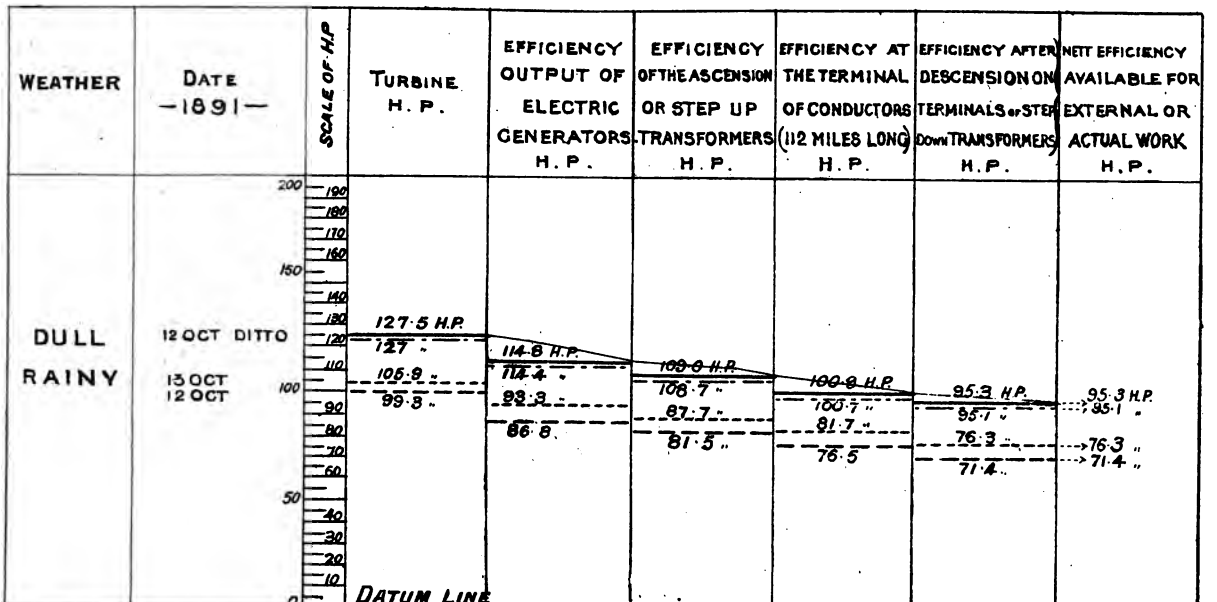
ELECTRIC POWER TRANSMISSION FROM COAL FIELDS,

WET AND DULL DAYS.

GRAPHIC DIAGRAM showing the absorption of energy by the elements constituting the Lauffen, Frankfort Line of Transmission of Electric Energy. Distance, about 112 miles Prepared by B. H. Thwaite from Herr Prof. Weber's Tables.



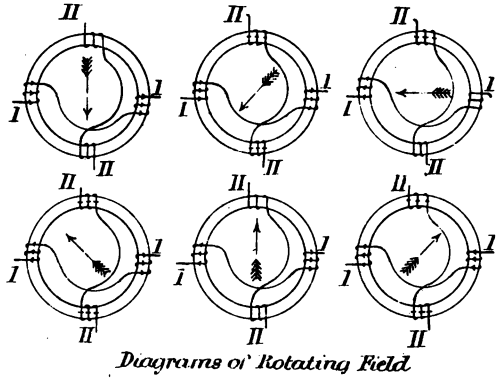
Tests on different days with different energy potentials shewn by different character of lines.

UNIV. OF MICH.

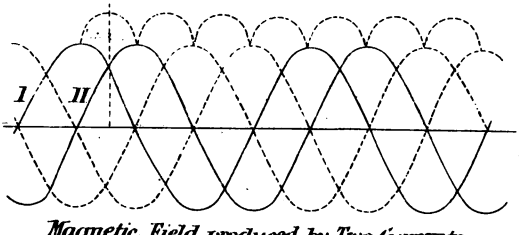
ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

MAGNETIC FIELD DIAGRAMS.

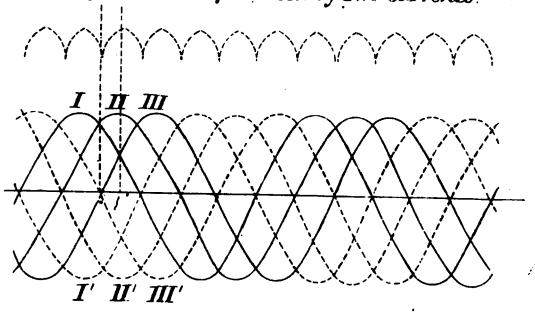
LAUFFEN-FRANKFORT TRANSMISSION INSTALLATION.



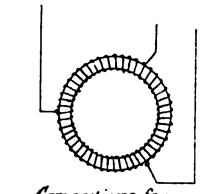
Diagrams of Rotating Field



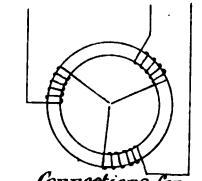
Magnetic Field produced by Two Currents.



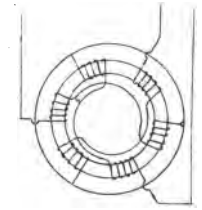
Magnetic Field produced by Three Currents



Connections for Multiple Phase Currents



Connections for Multiple Phase Currents.

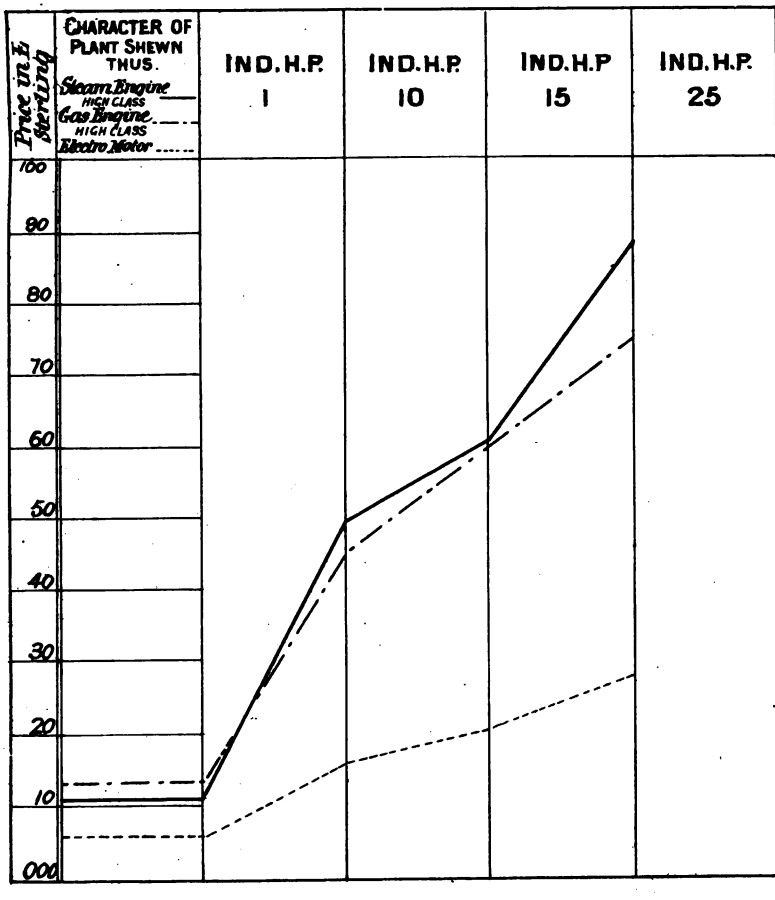


Connections for Multiple Phase Currents.

UNIV OF WYO.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

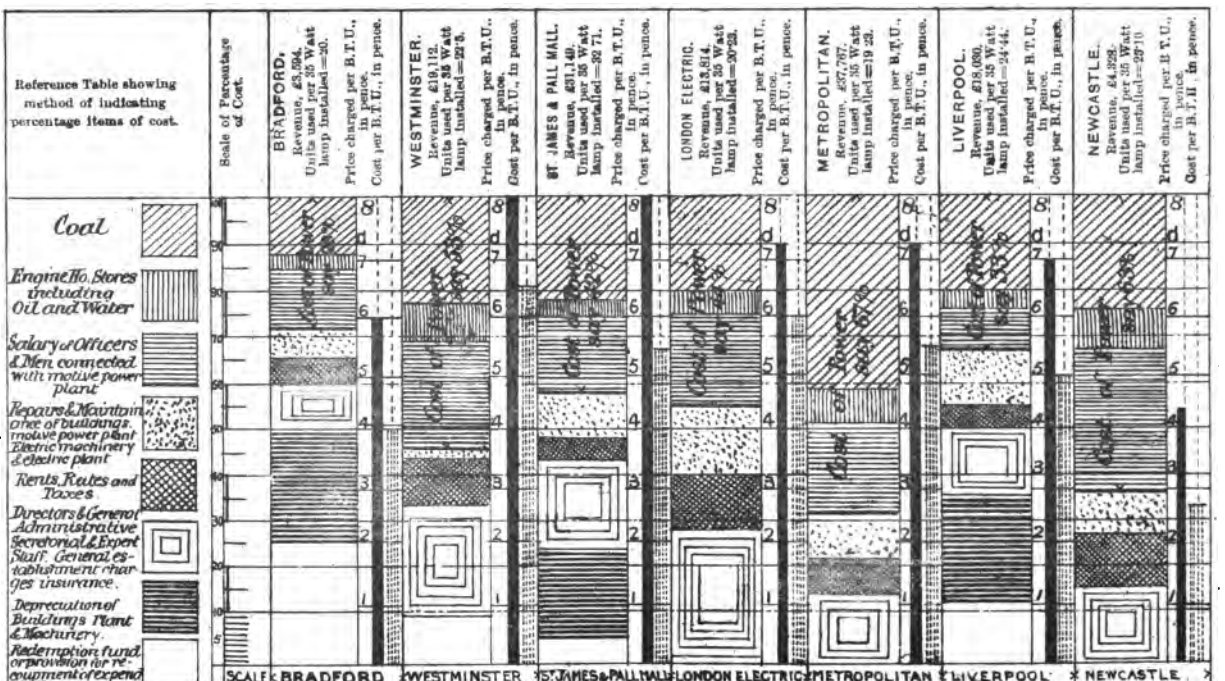
DIAGRAM showing respective cost of maintenance, interest, amortisation, and repairs of three forms of power installations.



B.H.Thwaite, C.E.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

GRAPHIC TABLE showing cost, and percentage elements of same, of units of electricity, delivered to customers from



PREPARED BY B.B. THWAITE.

Partly prepared from the admirable Reports Published in "Lightning," London.

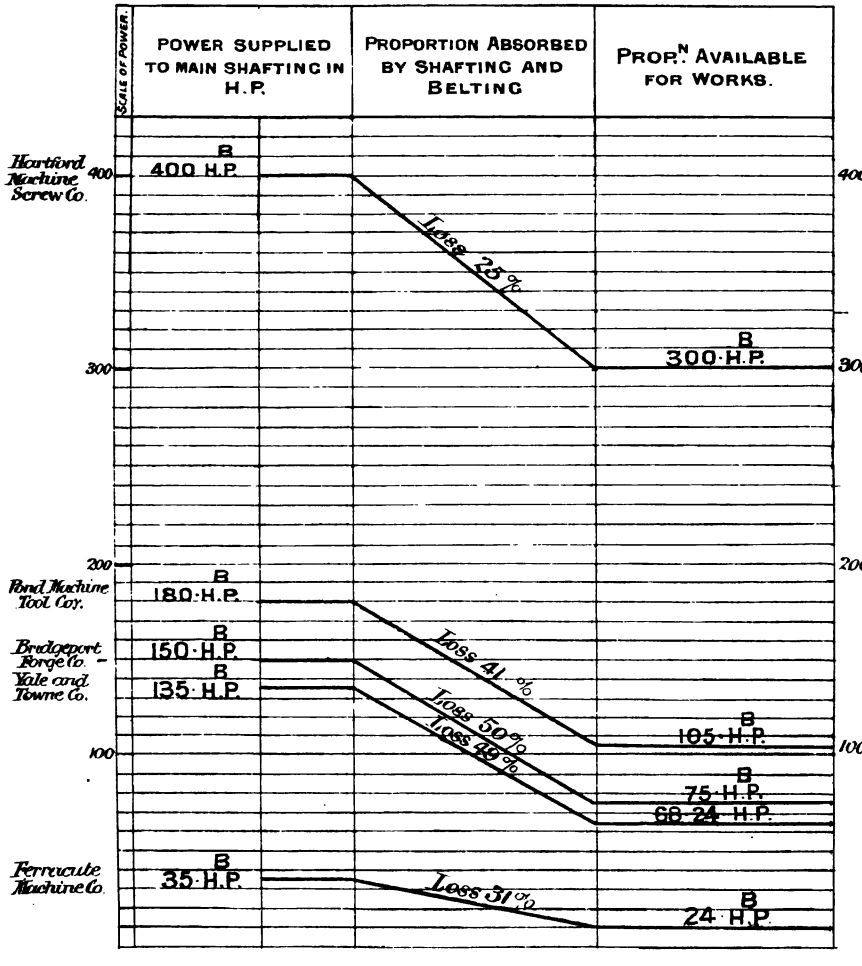
MANCHESTER ASSOCIATION OF ENGINEERS.

UNIV. OF MICH.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

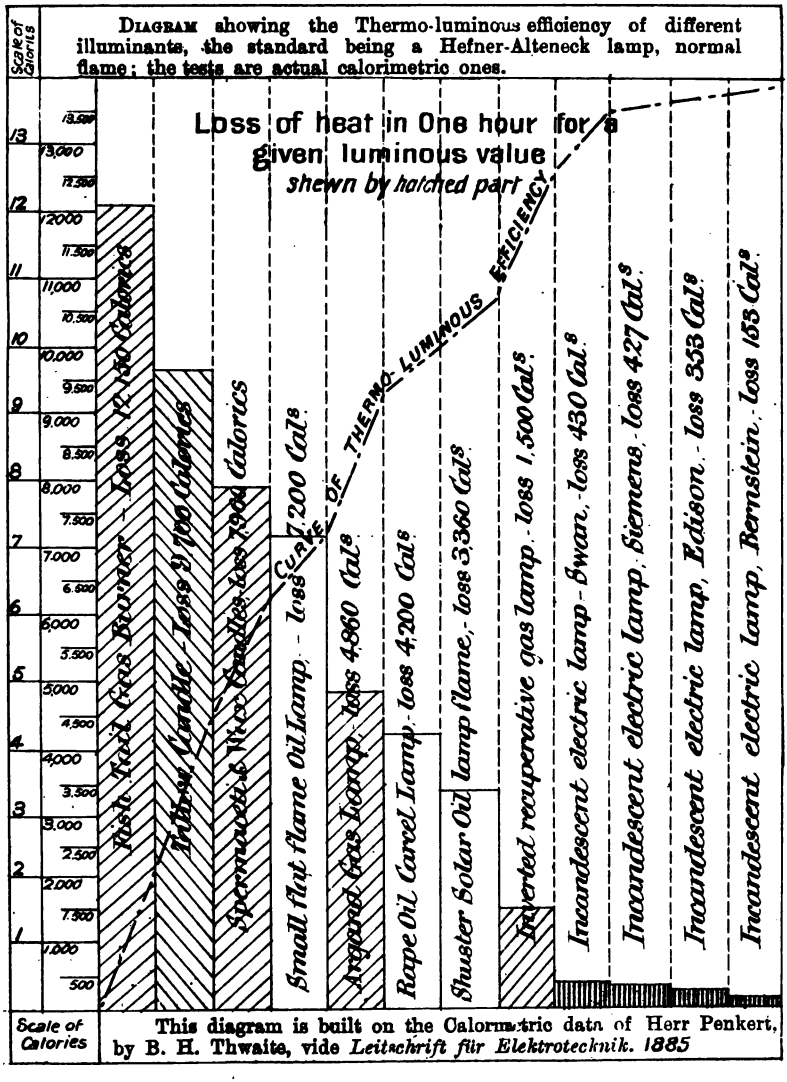
GRAPHIC DIAGRAM showing the absorption of power by Belting and Shafting.

Based on dynamometric investigations.



B. H. Thwaite, C.E.

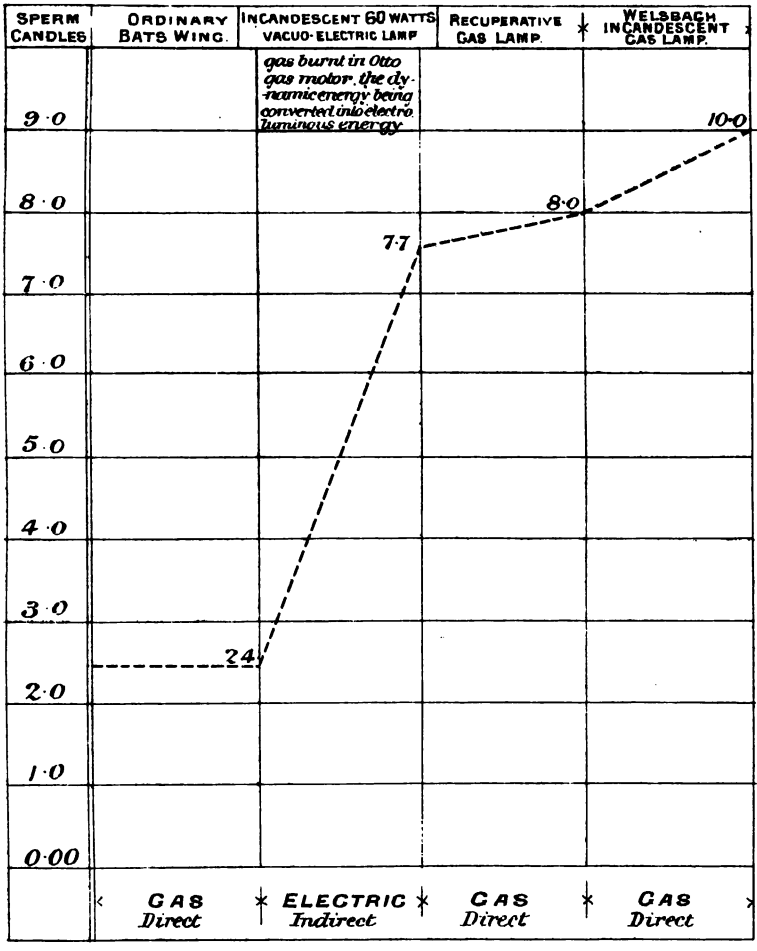
ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.



UNIV OF MICH.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing the Thermo-luminous Efficiency of different methods of burning gas, in functions of sperm candles of light, photometrically tested per cubic foot of gas burned per hour.



B.H. Thwaite, C.E.

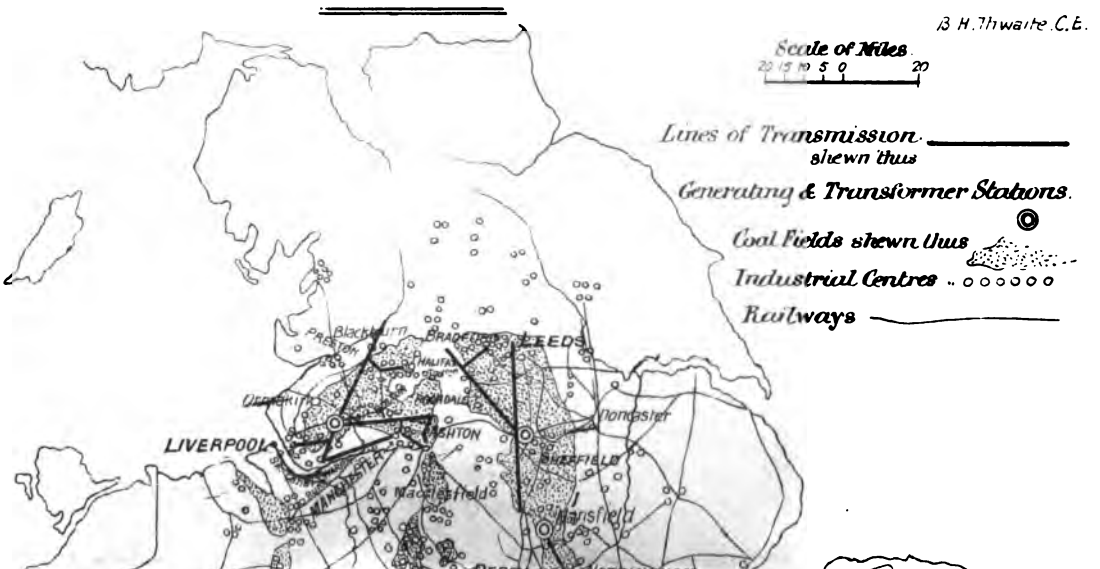
UNIV. OF MICH.

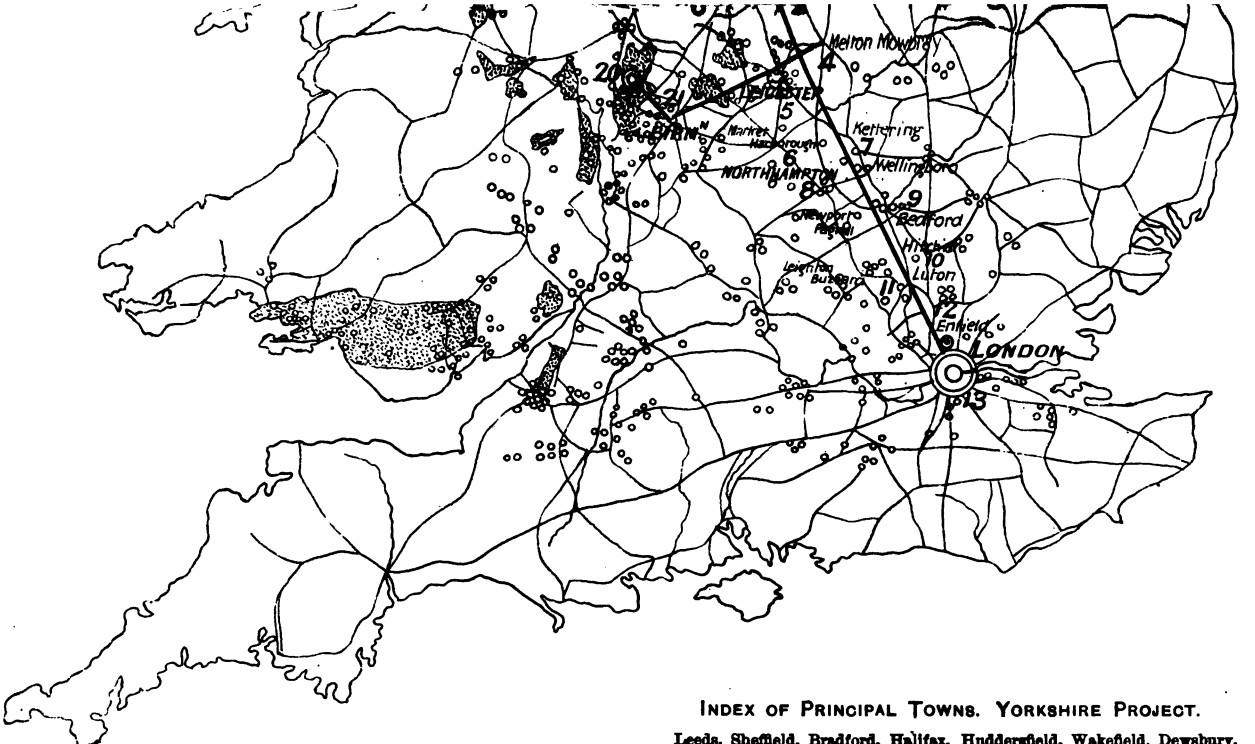
PLAN OF LINES FOR THE

TRANSMISSION OF ENERGY (ELECTRO-DYNAMIC)

FROM THE COAL FIELDS, TO THE

INDUSTRIAL CENTRES OF LANCASHIRE AND YORKSHIRE, THE MIDLAND COUNTIES, AND THE METROPOLIS OF GREATER LONDON.





Index of Principal Towns. Lancashire Project.

Manchester and the Ship Canal, Blackburn, Bolton, Preston, Liverpool, Oldham, Chorley, Ashton, Stockport, Warrington, St. Helens, Runcorn, Widnes, Heywood, Burnley, Bury, Rochdale.

Index of Principal Towns. Yorkshire Project.

Leeds, Sheffield, Bradford, Halifax, Huddersfield, Wakefield, Dewsbury, Rotherham, Stalybridge.

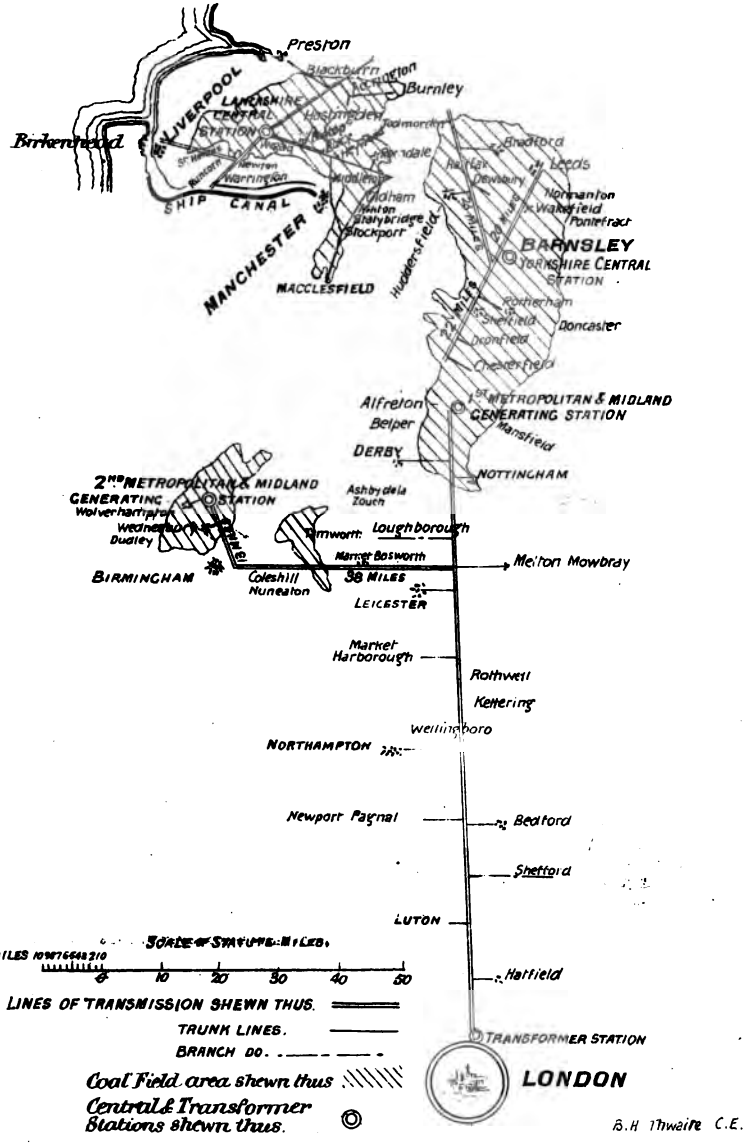
Index of Principal Towns. Midlands and Greater London.

1, Mansfield, 2, Nottingham, 3, Derby, 4, Melton Mowbray, 5, Leicester, 6, Market Harborough, 7, Kettering, 8, Northampton, 9, Bedford, 10, Hitchen, 11, Luton, 12, St. Albans, 13, Greater London, 20, Wolverhampton, 21, Birmingham.

UNIV. OF MICH.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

SCHEME OF ELECTRIC ENERGY TRANSMISSION FROM GENERATING STATIONS ON THE COAL FIELDS TO THE INDUSTRIAL CENTRES OF LANCASHIRE AND YORKSHIRE, THE MIDLANDS, AND THE METROPOLIS OF GREATER LONDON.



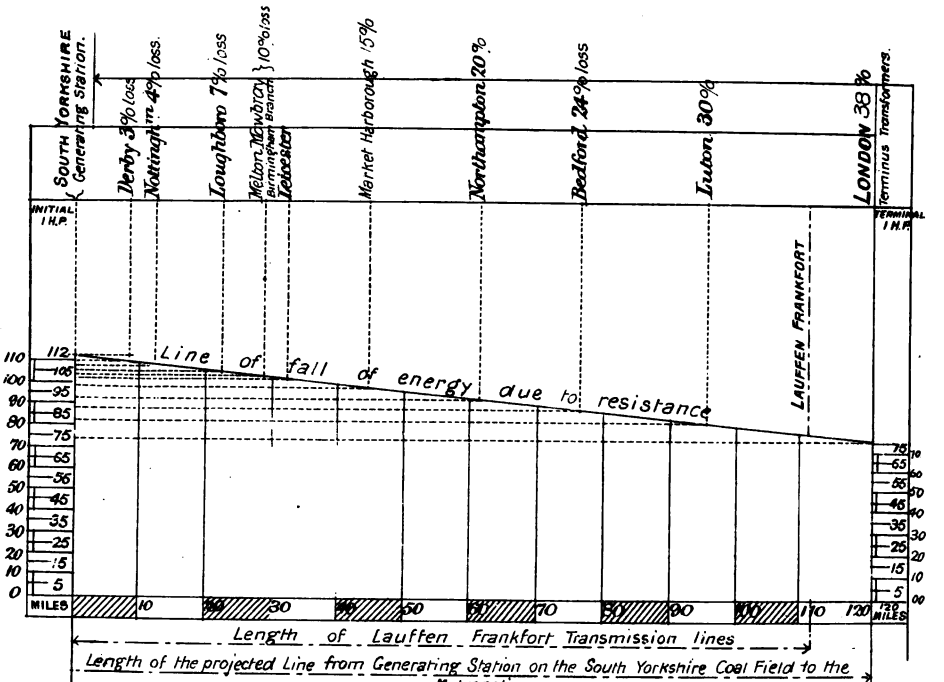
B.H Thwaite C.E.

UNIV
ZÜRICH

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

THE MIDLAND AND METROPOLITAN ELECTRIC TRANSMISSION OF POWER PROJECT

DIAGRAM showing fall of Energy due to Resistance, and based on the actual, and average results obtained from the Lauffen–Frankfort Transmission Project.



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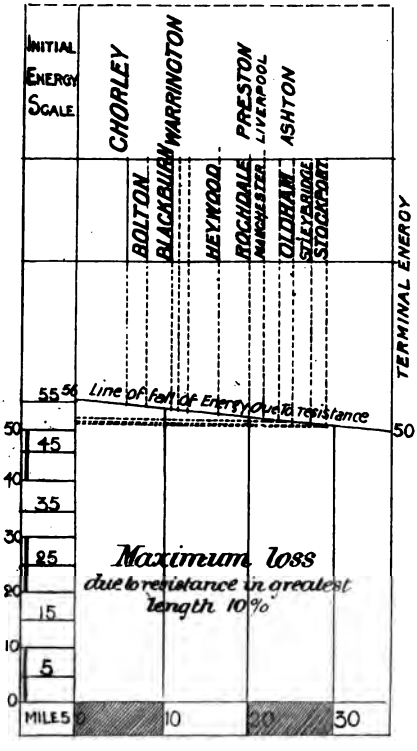
MICH.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

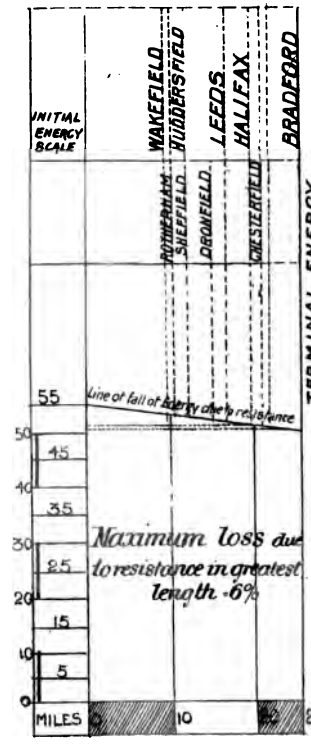
THE LANCASHIRE ELECTRO TRANSMISSION OF POWER PROJECT.

DIAGRAM showing fall of energy due to Resistance, and based on the results obtained from the Lauffen, Frankfort project.



THE YORKSHIRE ELECTRO TRANSMISSION OF POWER PROJECT.

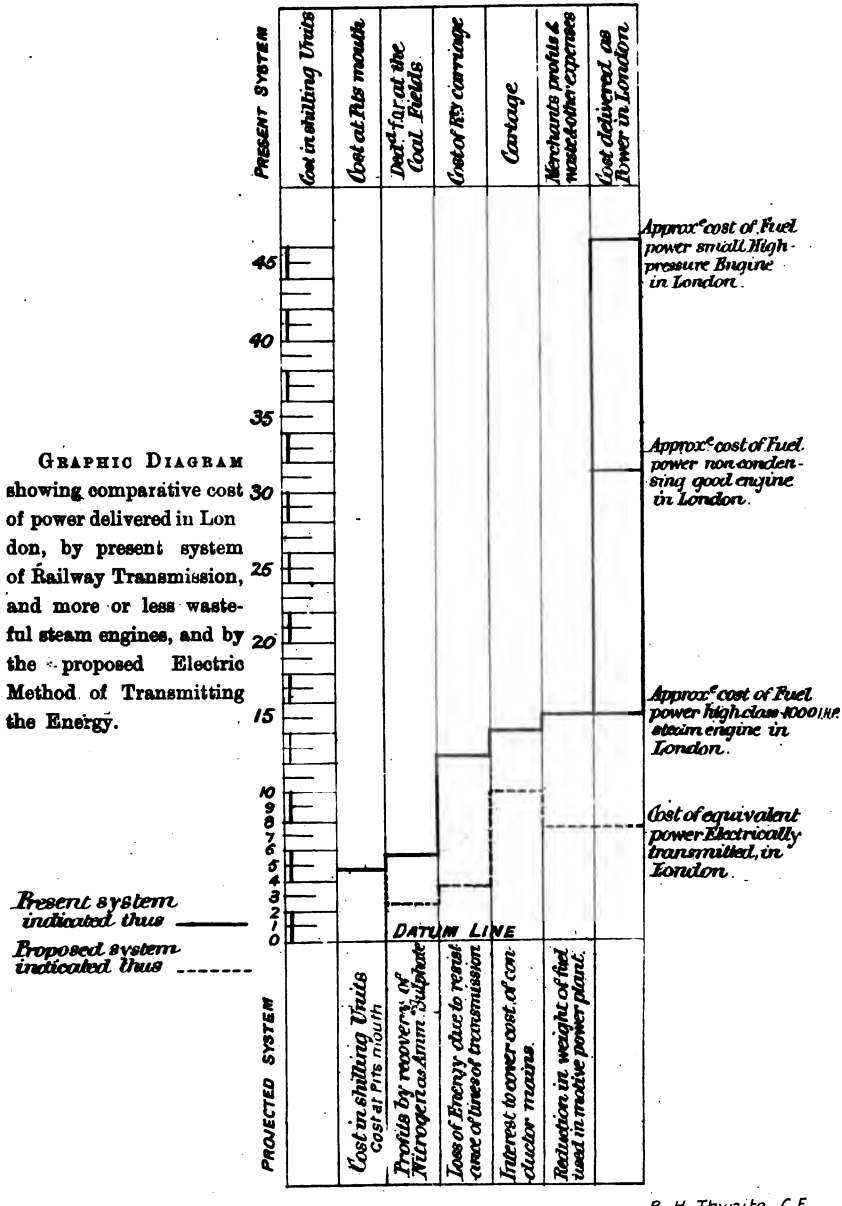
DIAGRAM showing fall of energy due to Resistance, and based on the results obtained from the Lauffen, Frankfort project.



B. H. Thwaite. C.E.

UNIV. OF WISCH.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.



GRAPHIC DIAGRAM showing comparative cost of power delivered in London, by present system of Railway Transmission, and more or less wasteful steam engines, and by the proposed Electric Method of Transmitting the Energy.

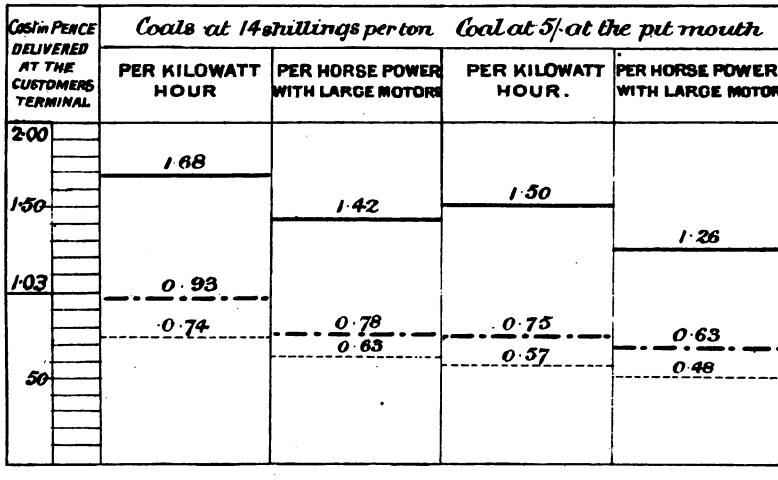
B. H. Thwaite, C.E.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

DIAGRAM showing cost of Electrical Horse Power delivered at the consumer's terminals from a central station, at a distance of 62 miles, total length of circuit being 186 miles. Based on Herr Prof. Salomon's figures, the cost of the central station steam power and electric generator plant being estimated at £250,000, for producing 10,000 I.H.P., made up thus:—

Land, buildings and steam engines..	£100,000
Electric conductor cables.....	45,000
Other Electrical plant	100,000
Total.....	£245,000, say £250,000.

The cable system is the Drehstrom (three wires), total length of cables, 558 miles for the 3 mains.



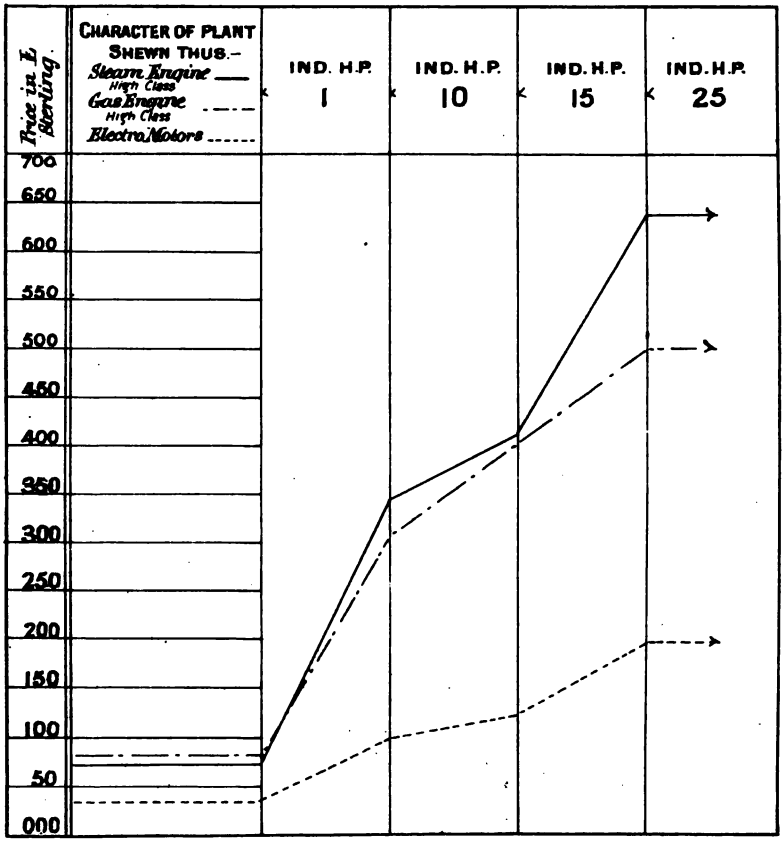
The line of cost for 1,000 working hours per annum is shewn thus ————
" " 3000 " " " " shewn thus - — · — · -
" " 5000 " " " " " " ----------

B. H. THWAITE.

UNIV. OF MICH.

ELECTRIC POWER
TRANSMISSION FROM COAL FIELDS.

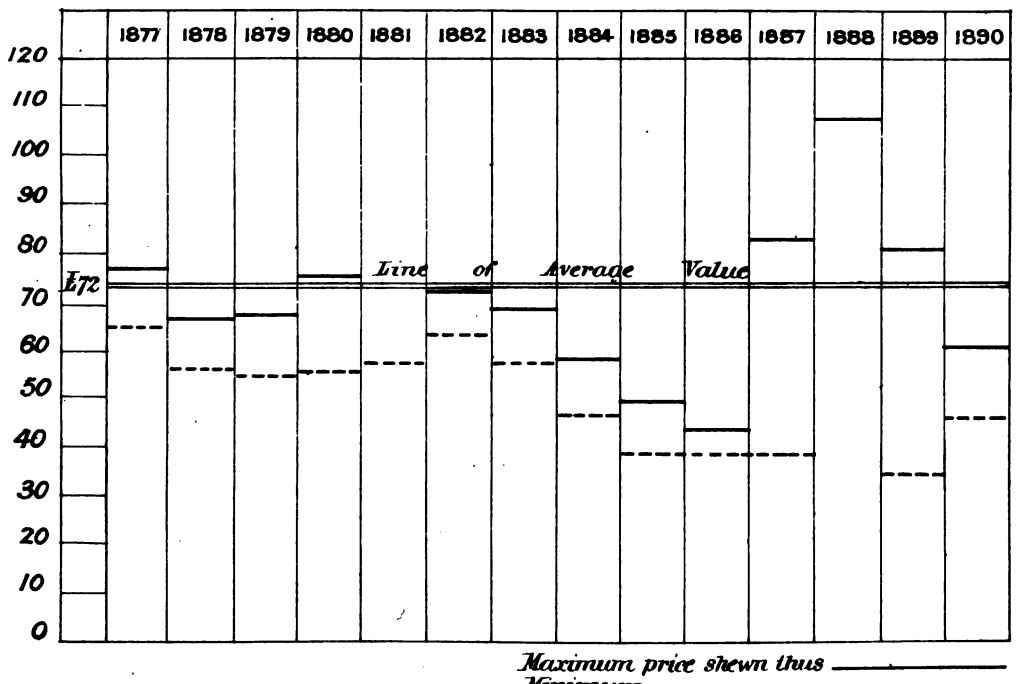
COMPARATIVE DIAGRAM of first cost of complete installation of respective powers generated by Steam Engine, Gas Engine, and Electro Motor Machines, based on Herr Prof. Redner's data. The Electro Motors are assumed to be driven by turbines or some other source of energy.



B.H. Thwaite C.E.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

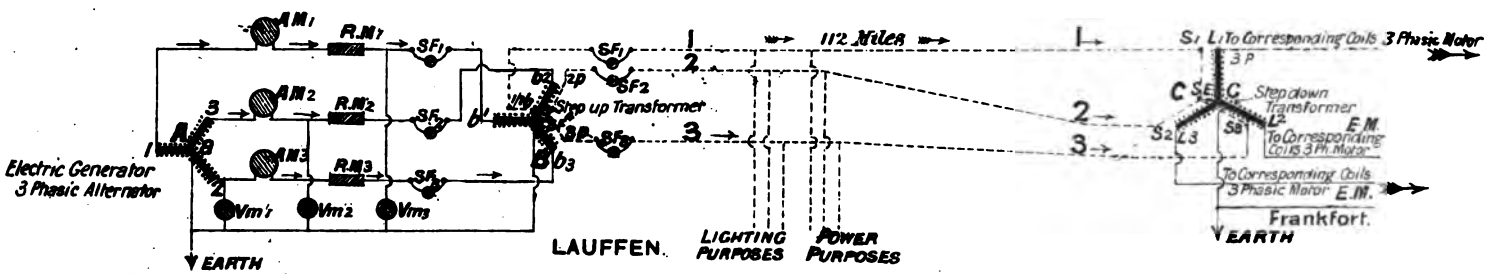
DIAGRAM showing the fluctuations in the price of Copper Bars; for 13 years ending 1890.
Price in £ sterling per ton. Quality, Chilian.



B. H. Thwaite. C.E.

ELECTRIC POWER TRANSMISSION FROM COAL FIELDS.

GRAPHIC DIAGRAM of the Lauffen-Frankfort Transmission Circuits. Safety, Measurement and Regulating Apparatus.



UNIV. OF MICH.

37TH Annual Report

OF THE COUNCIL.

1892.

MANCHESTER:

HERALD & WALKER, TYP., POOL FOLD CHAMBERS, OFF CHAPEL WALKS.

1893.

OFFICERS.

1893.

President:

MR. THOMAS DANIELS, M.I.MECH.E.

Past-President:

MR. G. B. GOODFELLOW, M.I.MECH.E.

Treasurer:

MR. HENRY MAINWARING.

Trustees:

MR. G. CARTER,
„ JOHN WEST, M.I.C.E.
MR. JAS. WALTHEW,
„ T. ASHBURY C.E.,
MR. ALDERMAN W. H. BAILEY, J.P.

Council:

MR. S. CHARLESWORTH,
„ H. BATES,
„ C. FARMER,
MR. A. G. BROWN,
„ G. DAVIS,
„ A. SAXON.

Librarian:

MR. J. GIBBON,
56, Herbert Street, Cheetham.

Secretary:

MR. FRANK HAZELTON,
63, Barrett Street, Old Trafford, Manchester.

Annual General Meeting

HELD AT THE

GRAND HOTEL, MANCHESTER,

10th December, 1892,

Mr. G. B. GOODFELLOW, M.Inst.Mech.E., President,

IN THE CHAIR.

The minutes of the previous meetings having been read and confirmed, and signed by the Chairman, he announced to the meeting the result of the ballot for the election of new members.

The election of President and other officers of the Association was next taken, with the result as set forth on opposite page.

Resolved unanimously.—"That the cordial thanks of this meeting be given to Mr. G. B. Goodfellow, for the interest he has taken in the welfare of the Association, and the excellent manner in which he has discharged the duties attaching to the office of President during the past year."

Mr. Goodfellow returned thanks.

Resolved unanimously.—"That the thanks of the Association are justly due and are presented to the Past-President and other Officers of the Association for their co-operation with the President, and for their zeal on behalf of the Association during the past year."

Mr. H. Mainwaring acknowledged the compliment on behalf of himself and the other officers.

Resolved unanimously.—"That the Annual Dinner be held as usual; all arrangements to be left in the hands of the Council."

ANNUAL REPORT OF COUNCIL.

1892.

IN presenting the 37th Annual Report of Proceedings, the Council have pleasure in congratulating the members upon the continued success and progress of the Association.

To the membership roll during the year have been added—

12 Honorary Annual Members.
14 Ordinary Members.

Total 26

but taking into account the loss by death, resignation, and erasure, the effective addition to the membership amounts to 5, bringing up the total number of names of all classes on the roll to 350, namely :—

25 Honorary Life Members.
107 Honorary Annual Members.
218 Ordinary Members.

Upon reference to the Financial Statement as certified by the auditors (see appendix), it will be seen that the balance standing to the credit of the Association after payment of all accounts due up to the 31st December, amounts to £3,305. 12s. 3d., as against £3,181. 1s. 6d , at the close of the preceding year, thus showing a surplus of £124. 10s. 9d. on the year's working.

It is with profound regret the Council have to record that during the year death has removed the following members, brief memoirs of whom are appended on pages 277 to 281. In accordance with resolutions, letters of condolence and sympathy

have been forwarded to the widows and families of the deceased members:—

Asquith, E.	Manchester.
Birtwistle, R.	Haslingden.
Cryer, T.	Manchester.
Farmer, Sir J.	Salford.
Nasmith, John	Manchester.
Richardson, Wm.	Oldham.
Taylor, James	Do.

The following gentlemen have resigned their Membership in the Association during the past year —

Hacking, T.	Salford.
Leigh, James	Manchester.

The following gentlemen have ceased to be Members of the Association during the past year:—

Carter, Claude	Birmingham.
Crighton, R.	Manchester.
Crighton, J.	Do.
Duncan, D. S.	Warrington.
Elliott, T.	Leeds.
Longson, J.	Glossop.
McDonald, J.	Manchester.
Millen, R.	Do.
Perkins, S.	Do.
Sorabgee, S.	Do.
Wrightson, W.	Do.
Williamson, E.	Sheffield.

The following gentlemen have been added to the Membership Roll during the year:—

HONORARY MEMBERS.

Musgrave, W. M.	Bolton.
Adamson, Jos.	Hyde.
Sample, W. S.	Patricroft.
Saxon, G.	Openshaw.
Parker, J.	Manchester.
Gendall, W. H. S.	Bury.
Gass, G. P., Jun.	Bolton.
Brown, R.	Northwich.
Capes, H.	Do.
Hall, J.	Bury.
Sykes, E.	Huddersfield.
Kay, James	Bury.

ORDINARY MEMBERS.

Collier, C. H. - - -	Salford.
Ormerod, W. - - -	Manchester.
Pickup, E. A. - - -	Hyde.
Gregory, R. - - -	Bolton.
Goodman, J. - - -	Leeds.
Booth, W. S. - - -	Salford.
Howarth, E. - - -	Hulme.
Wood, W. - - -	Openshaw.
Harrison, J. - - -	West Gorton.
McClement, D. G. - -	Manchester.
Clarkson, James - -	Openshaw.
Widdowson, W. J. - -	Manchester.
Widdowson, A. J. - -	Do.
Blears, T. - - -	Do.

From the following list it will be seen that the papers read during the year have been on subjects of considerable importance, as may be gathered from the exceptionally large attendances of members at these meetings, and the interesting discussions which ensued:—

PAPERS READ DURING THE YEAR.

9th Jan.—Inaugural Address by the President, Mr. G. B. Goodfellow, M.I.Mech.E., Hyde.

13th Feb.—On "The relative economy of the Triple Expansion, Compound and Simple Engines," by Mr. W. J. Jenkins, Assoc. M.I.C.E., of Manchester.

27th Feb.—On "The Manufacture of Iron," by Mr. H. Webb, of Bury.

12th Mar.—On "Supplementary Speed Governors," by Mr. J. Williams, of Manchester.

26th Mar.—On "Dry-Air Refrigerating Machinery: its commercial value," by Mr. W. G. Quicke, of Manchester.

9th April.—On "Paper Making Process and Machinery," by Mr. J. B. Bennett, M.I.C.E., of Edinburgh. Communicated by Mr. A. Rea, of Manchester.

22nd Oct.—On "Comparison of Friction in Cotton Mill Engines and Gearing to the actual work done," by Mr. Alfred Saxon, of Manchester.

12th Nov.—On "The Economic Possibilities of the Generation of Electro-Motive Force in the Coal Fields and its application to industrial centres," by Mr. B. H. Thwaite, of London.

26th Nov.—Discussion on ditto.

ANNIVERSARY DINNER.

The Thirty-sixth Anniversary Dinner was held on Saturday evening, 23rd January, at the Grand Hotel. There was a large gathering of members and friends. Mr. G. B. Goodfellow, president, occupied the chair, and among those present were Alderman W. H. Bailey, Messrs. J. W. Sidebottom, M.P., Henry Webb. John Craven, Joseph Adamson, S. Dixon, A. Muir, M. Longridge. Letters of apology were announced from Sir John Harwood, who was unable to attend through indisposition, from Dr. Ward, principal of Owens College, from Mr. John West, the ex-president of the Association, and from Mr. Thomas Ashbury. The general company numbered 112.

Mr. HENRY WEBB, in proposing "Our Municipal Corporations," said we had in Manchester a corporation which was a model to the whole country. He understood that in the Salford Corporation the members were of a loving disposition. (Hear, hear, and laughter.) He was sure the ratepayers were greatly indebted to those gentlemen who devoted a large measure of their time to attending to the public interests. (Hear hear.)

Alderman BAILEY replied to the toast. He expressed regret that Sir John Harwood was not present, as he would have liked in Sir John's presence to have expressed his satisfaction at the splendid manner in which the Manchester Corporation was assisting that great enterprise the Manchester Ship Canal. It was very gratifying to know that all the directors were working cordially together, with a will and determination to finish the canal, and that before very long. Thoughtful men must feel that the time was rapidly coming, if it had not already come, for the consolidation of municipal institutions. There ought to be only one governing body. School Board work, the care of the poor, sanitary requirements, lighting, and all other matters connected with the welfare of the burgesses, ought to be entrusted to one body. There was a vast amount of extravagance

at the present time, especially in connection with their able-bodied paupers, who had never done a day's work in their life, and never intended to do if they could help it. These able-bodied vagabonds ought to be placed under the care of the Watch Committee, and then perhaps it would be possible to bestow the care a Christian people might be expected to bestow on those who were poor because of infirmity and old age. Speaking more distinctly as to the work of our municipal institutions, Alderman Bailey said the Manchester Corporation were taking steps for the lighting of the city by electric light, and he believed that Salford would do so shortly. There was a great scope for municipal work. There was no limit to what might be done for the burgesses. Old England at present could boast of a system of automatic republics where the burgesses govern themselves. No country, ancient or modern, could show a greater amount of liberty than was enjoyed in our English towns. There was one painful thing, however, and that was in the matter of the election of the aldermen. Some dangerous people said they should be elected by the burgesses. (Laughter.) The people who said that would want to do away with the House of Lords next, and then what would become of Old England? (Laughter.) We should be careful what we did, for among the great bulwarks of this happy England of ours might be considered the aldermanic bench. (Renewed laughter.) If they wanted to measure the civilization of any man they should see the way in which he treated an English alderman, and the dangerous doctrine to have the alderman elected by the people should be suppressed, (Laughter.) He was sorry to see that Salford did not get the credit due to her. She was well to the fore in the matter of municipal institutions, and was the first to call attention to the subject of gas frauds. (Hear, hear.)

Mr. J. W. Sidebottom, in proposing "Prosperity to the Association," said under any circumstances it would be a pleasure to propose such a toast, but the pleasure was considerably enhanced because of the fact that their president was a gentleman connected, like himself, with Hyde, a gentleman with whom and with whose work he had been acquainted for many years, and who was known throughout the district not

only for his splendid work but for the manner in which he upheld the best traditions of his profession. Such associations as that in connection with which they were met must be very valuable in promoting the prosperity of the engineering profession. In listening to their annual report, no one could doubt that if the Association advanced along its present lines its prosperity was assured. He entirely agreed with the president when he said in his inaugural address that he saw no reason why in time the Association should not rank second to none in the country. (Applause.)

The PRESIDENT, acknowledging the toast, said the Association had grown very much of late years. Many present could remember the formation of the Association, and its growth had gone on to such an extent, and, he hoped, would go on increasing in the future, so that they would be compelled to have a larger room in which to hold their meetings. (Hear, hear.)

Mr. JOHN CRAVEN gave the toast of "Our Guests," which was responded to by Mr. ALFRED ATKINSON, a delegate from the Leeds Association of Engineers, and Mr. JOSEPH ADAMSON, Hyde.

Mr. M. LONGRIDGE proposed "The Engineering Profession." He remarked that it was difficult to say where engineering began and where it ended. It was, perhaps, divided particularly into two great branches, the civil engineers and the mechanical engineers. For many years the civil engineers in some sort of a way were considered to hold rather a superior position, something like the barristers held in the law. But that had been changed now. He thought the mechanical engineer now was the man who stood at the head of his profession, who had the most difficult problems to tackle, problems involving the most exact kind of calculation and dealing with the most abstruse of nature's laws. The work they did would live after them. If they all tried to do their best in their high calling he was sure English engineering would continue to hold the prominent place it had held in the world. (Hear, hear.)

Mr. W. M. MUSGRAVE (Bolton), in responding, said he thought the educational system was going to assist engineering greatly. For a long time there had been great difficulty in getting young men to study engineering, for wages in that occupation were not so good to begin with as in other businesses.

"The Health of the Chairman," was proposed by Mr. S. DIXON, and acknowledged by the PRESIDENT.

Some enjoyable musical selections were given by Messrs. Greenwood, Blacow, Griffiths, and Maltby, and Mr. Greenwood also contributed a humorous sketch entitled "A Trip to the Isle of Man."

LIBRARY.

The Council are pleased to report that the Library continues to fill a very important place in the Proceedings of the Association. The following new books have been purchased :—

Title of Book.	Author's Name.
Atlantic Ferry, The.	Maginnis.
Applied Mechanics.	Lanza.
Dynamos.	Bottone.
Dynamometers.	Flather.
Electric Railway in Theory.	Crosby.
Electric Railway.	Hering.
Electricity, Handbook of.	
Engineering Chemistry.	Phillips.
Ironfounder.	Bolland.
Factories and Workshops, Our.	Thwaite.
Milling Machinery.	Hasluck.
Roll-Turning.	Spencer.
Triple-Expansion Engines.	Leask.
Steam Boilers.	Munro.

The Council have pleasure in acknowledging the following donations, and in expressing their thanks to the donors for the valuable and acceptable additions they have thereby made to the Library :—

Visit of the Iron and Steel Institute to America. By H. Webb. Presented by the Author.

Students' Cotton Spinning. By J. Nasmith. Presented by the Author.

Aid to the Injured.
Metallurgy. Percy. } Presented by Mr. H. Webb.

The Association Exchange Transactions with the following :—

American Institute of Mining Engineers.
" Mechanical Engineers.
Canadian Society of Civil Engineers.
Canadian Institute, Toronto.
Civil and Mechanical Engineers' Society.
Engine, Boiler, and Employers' Liability Insurance Company.
Franklin Institute, America.
Institution of Civil Engineers of England.
" Engineers and Shipbuilders in Scotland.
" Mechanical Engineers.
" Civil Engineers of Ireland.
Iron and Steel Institute.
Liverpool Geological Society.
" Engineering Society.
Manchester Geological Society.
" Steam Users' Association.
" Statistical Society.
" Literary and Philosophical Society.
Midland Institute of Mining, Civil, and Mechanical Engineers.
Mining Association and Institute of Cornwall.
Mining Institute of Scotland.
National Boiler Insurance Co.
North of England Institute of Mining and Mechanical Engineers.
North-East Coast of Engineers and Shipbuilders.
Philosophical Society of Glasgow.
Royal Scottish Society of Arts.
Society of Arts.
South Wales Institute of Engineers.
Society of Engineers.

The following Publications are received periodically :—

Colliery Guardian.
Electrical Review.
Engineer.
Engineering.
Industries.
Iron.
Iron and Steel Trades' Review.
Marine Engineer.
Mechanical World.

With the view of increasing the Library, the Council respectfully invite the members to make donations of books, original pamphlets, drawings, &c. To enhance its value, the Council are always willing to receive suggestions for suitable additions to the Library, entries of which may be made in the "Recommendation Book."

OPENING OF DISCUSSION SESSION.

The 87th Discussion Session was opened on Saturday, October 8th, by a Social Meeting at the Grand Hotel, about 80 members being present. In the unavoidable absence of the President, the chair was occupied by Mr. T. Ashbury (Past-President), who during the interval in the musical programme, drew attention to the subjects for the session.

The following gentlemen contributed to the musical programe:—Messrs. W. Cooper, J. P. Cooper, H. Glynn, R. M'Clean, A. F. Burgess, W. Spary, and S. Boswell, to whom a vote of thanks was cordially passed for their services.

SAIL ON THE WEAVER AND MANCHESTER SHIP CANALS.

With the object of affording the members an opportunity of inspecting the completed portion of the Manchester Ship Canal, the Council specially chartered a steamer to convey them from Northwich to Eastham and Liverpool, on Saturday, July 2nd. The party, numbering about 230 ladies and gentlemen, left the Central Station at 10-23 a.m. by special train for Northwich, and on arrival proceeded to the "Crown and Anchor" Wharf, from which place two steamers conveyed the party as far as Weaver's Pool. On reaching the latter place they all got on board the "Manx Fairy," which then steamed for Eastham and Liverpool, arriving at the landing stage about 5-30 p.m., when the official programme terminated.

In concluding their review of the work of the past year, the Council desire especially to express their cordial thanks to those members who have read papers or contributed to the discussions. It is to such gentlemen that the Association is largely indebted for its present position and influence. Its future career and usefulness, however, is in the keeping of each and every member. Let each come forward to assist, and the Association will undoubtedly become a power and success beyond the most sanguine anticipations of its promoters.

OBITUARY.

EDMUND ASQUITH joined the Association in 1858 as an Ordinary Member, and from that to the present year was more or less prominent in all its proceedings. He was elected a Trustee in 1875, and in the year 1880 was President of the Association. He was rarely absent from the Council and General Meetings of the Association, and by his assiduous attention to the duties of his office he constantly evinced his desire to advance the interests of the Association. Mr. Asquith was a native of Yorkshire, and came to Manchester many years ago, and found employment as a working mechanic. Subsequently he commenced business on his own account in Pump Street, and afterwards removed to Mather Street, where, up to the time of his death, he carried on business as a Machinist and Hydraulic Engineer. Mr. Asquith for nearly seventeen years was a familiar figure in Manchester municipal life. At the general election in 1875 he was selected by the Liberals of St. Clement's Ward to oppose the return of Mr. George Anderton, who had been a representative of the ward for six years. After a severe fight Mr. Asquith was returned by a majority of 143 votes, and continued to represent St. Clement's Ward without a break till 1887, when he became an Alderman. Rugged in appearance and plain and brusque in speech, Alderman Asquith prided himself almost above everything else upon being a practical man. His experience as a mechanical engineer has been of great service to the Corporation. At all times he gave loud voice to his opposition to anything which he thought savoured of extravagance, either in advances of salary to officials or any other proposals in which the expenditure of the rates was concerned.

He died suddenly on the 22nd February, 1892, in the 63rd year of his age.

RICHARD BIRTWISTLE was born at Haslingden, near Manchester, on 27th March, 1834. After serving his apprenticeship to engineering, he entered into partnership with Mr. Samuel S. Stott, with whom he purchased in 1866, the engineering and millwright business of his late father-in-law, Mr. John Lindsay, at Laneside Foundry, Haslingden. At that time the place was of small dimensions, but by his ability and energy it rose to be ranked among the leading engineering establishments in the country, finding employment for a large number of workpeople. On the death of his partner more than two years ago, he became the sole proprietor of the business. He died at Southport, on 18th April, 1892, in the fifty-ninth year of his age.

He was elected an Honorary Member of the Association in 1873.

THOMAS CRYER was born at Bradford, Yorkshire, on 5th Nov., 1849. He served his apprenticeship in the works of Messrs. Smith, Beacock, and Tannett, Leeds, subsequently entering the drawing office. Having been very

successful in the Science and Art, and City Guilds examinations, Mr. Cryer eventually adopted teaching as a profession, and at the time of his death was lecturer in Mechanical Engineering at the Manchester Technical School. He published, in conjunction with his friend, Mr. H. G. Jordan, several text books in Mechanical engineering, which, judging from their enormous circulation, were admirably adapted for the purposes intended.

He joined the Association as an Ordinary Member in December, 1885, and in 1888 he was elected a member of the Special Technical Educational Committee, the result of whose deliberations was the pamphlet published by the Association entitled "The Technical Education of Engineers," issued the same year to the members. After a painful illness, extending over a period of nine months, Mr. Cryer died on March 2nd, 1892, leaving a widow and seven children.

Mr. Cryer was of an exceptionally engaging disposition, and by his death the Association has lost a valuable member and his acquaintances a friend whose place will not readily be filled.

Sir James Farmer was a life-long resident in the borough of Salford, and was the founder of the firm of James Farmer and Sons, engineers and millwrights, Adelphi Street, which business has been conducted during the later years of Sir James's life by his sons, Mr. Andrew W. Farmer, and Mr. James S. Farmer. The leading manufactures of the firm are bleaching and cotton spinning and weaving machinery, but in recent years they have largely developed a new department in the production of machinery and apparatus for sewerage utilisation and disposal. Although always of quiet and unostentatious disposition, Sir James was induced to enter the Corporation of Salford so far back as 1864, and continued a member until his decease. From the first of his connection with the Salford Corporation he began to take great interest in the water supply of the borough, his engineering training giving him special knowledge on the subject. In November, 1864, immediately after his election, he was placed on the Water Committee, and two years later he was elected chairman of the committee, which important position he continued to occupy during the whole period of his membership of the Council. Sir James also took an active part in connection with the fire brigade of the borough, to whose efficient equipment he paid great attention. For many years he was chairman of the Fire Brigade Sub-Committee. After serving as a councillor for 16 years, he was raised to the dignity of an alderman in November, 1880, and was assigned to Regent Ward. He succeeded Alderman Makinson as Mayor of the borough in November, 1885, and held that office for two years. During the term of his second Mayoralty the Jubilee of Queen Victoria's reign was celebrated, and in the loyal borough of Salford the event was made the occasion of extensive rejoicings, in which the Mayor took the lead. As Salford is one of the largest boroughs in the kingdom, notwithstanding that it is overshadowed by its immense neighbour, it received due recognition in the distribution

of the Jubilee honours, and, on the morning of the aniversary of the Queen's accession, the then Mr. Alderman Farmer received intimation that her Majesty had been pleased to confer upon him the dignity of knighthood. On May 4th, 1887, the borough was gaily decorated on the occasion of the visit of the Prince and Princess of Wales, who came to Manchester to open the Royal Jubilee Exhibition at Old Trafford. At Peel Park Alderman Farmer presented to the Prince of Wales an address of welcome. The deceased was a justice of the peace for the borough.

He entered the Association in 1875, as an Honorary Member. He died on the 21st October, 1892, in the 68th year of his age, and was interred at Salford Cemetery.

Mr. JOHN NASMITH was elected an Ordinary Member of the Association in 1859, and in 1863 occupied the Presidental chair, and of the many gentlemen who have been connected with the Association since its foundation, few have been more devoted to its interests, or up to recent years, taken a more active part in its management. Although recently by increasing age and by his many duties and occupations he was prevented from taking that active part in the later affairs of the Association that he did in its earlier history, he never failed to exhibit the warmest solicitude for its welfare. Mr. Nasmith was a native of the south of Scotland, but passed his early years in Carlisle, where he was apprenticed to the trade of engineer. He came to Manchester about 1845, and obtained employment with Mr. (afterwards Sir) William Fairbairn. In 1850 he entered the service, as foreman, of Mr. John Hetherington, who then occupied a portion of Fairbairn's works in Store Street. Mr. Nasmith has been since that date continually in the service of the same firm, and at the time of his death was one of its managing directors. He was a thorough mechanic and never became antiquated, being fertile in devising improved methods of producing work at a quick and cheap rate. He had no bent towards public work, but for many years took an active part in the work of the Holt Town Ragged School, not only teaching on Sundays, but becoming personally acquainted with his scholars and their circumstances. In the course of several business journeys to the United States he made a large circle of friends, and in the cotton spinning districts was held in high esteem by many manufacturers. Quiet, unassuming, and courteous in manner, he gained the regard of those who came in business contact with him, and the native shrewdness of his character, enlarged and strengthened by an intelligent observation of men and things in different countries, enabled him to form sound and correct judgments.

He died on the 5th of April, 1892, in the 70th year of his age, leaving a widow and two sons to mourn his loss. Mr. Nasmith's memory will long be cherished by those members who were associated with him in the early days of the Association, and who will readily recall to mind the times when his calm and peculiarly suasive arguments has been the means of immediately changing a discussion of an acrimonious tendency to one of complete unanimity.

WILLIAM RICHARDSON was born at Horbury, near Wakefield, on the 11th of August, 1811, and the year following his parents went to reside at Cooper Bridge, near Huddersfield, his father having obtained an appointment under the Calder and Hebble Navigation Company. Born with a strong and vigorous constitution, at an early age he was sent to the village School, and remained there until he was eight years old, when he was set to work to assist in the domestic Hand Loom Weaving Industry. When eleven years old he was sent to the cotton mill of Mr. Thomas Haigh, Colne Bridge, where he was found suitable employment in connection with the various machines used for the preparing and spinning of Cotton until 1823, when, having been bound apprentice, he entered the mechanic's shop connected with the mill, and remained there until 1833, having during this period diligently applied himself to remedy the defects of his scanty education, and make himself practically acquainted with every machine in the mill, as well as with the water wheel and its connections, by which the machinery of the mill was driven. On leaving Cooper Bridge he removed to Marsden, and entered the service of Messrs. Taylor Bros., Engineers and Boilermakers. In 1834 he entered the service of Messrs. Hibbert and Platt, Hartford Works, Oldham, already a well reputed and rising firm of Textile Machine Makers. In 1837, trade in Oldham being slack, in order to gain further experience and knowledge, he left Oldham for London, and succeeded in obtaining employment with Messrs. Beal & Henderbury, East Greenwich, where he learned the use of gauges and templets, and obtained an insight into the principle of inter-changeability and accurate workmanship, which he never afterwards forgot. After working in London about six months he returned to Oldham, Messrs. Hibbert and Platt having in the meantime become busy. After Mr. Richardson's return to Hartford Works, he applied himself with such diligence and success to the re-modelling of the Scutcher Department that his employers advanced him to a leading position in the management of the business. From this time the career of Mr. Richardson becomes part of the history of Hartford Works. The building of the Hartford New Works, Werneth, and the consequent transference of several important departments, left Mr. Richardson free to devote himself to the remainder of the business carried on at the Old Works, with which he had always been more particularly connected. After the building of Hartford New Works, the still further growth of the business led to the establishment of, what may be called, the outside branches, such as the Forge for the manufacture of wrought iron, the Brick-works for the manufacture of patent bricks, and the Collieries and Coke Ovens. With all of these Mr. Richardson was specially associated, taking a leading part in their installation and development; on all these additions to the business he has left the impress of his judgment and ability.

Although the records of the Patent Office show that Mr. Richardson was a prolific inventor, it was more in the character of constructor and organizer that his strength lay. A skilful handicraftsman, capable of enduring the most exhausting fatigue, well informed on all matters connected with his

business, possessed of sound judgment, indomitable resolution, perseverance, and the love of his calling, he was, in cases of difficulty, full of resources and a tower of strength.

Mr. Richardson took great interest in the progress of his adopted town, of which he was a Borough Magistrate and for a time a Town-Councillor, promoting its educational interests, especially in the direction of technical education, having been President both of the Oldham Lyceum and of the Oldham Science and Art School. He was a generous benefactor to the Oldham Infirmary. He became a Member of the Institution of Mechanical Engineers in 1859, and was also a Member of the Iron and Steel Institute from its foundation in 1869. Mr. Richardson was also a member of other Scientific and Technical Institutions.

The business of Hartford Works, in 1837, was changed from the style of Hibbert & Platt to that of Hibbert, Platt & Sons. In 1854 Messrs. John and James Platt, having become sole proprietors of the business, decided in consequence of its growth to enlarge the partnership by admitting the chief Heads of Departments, viz: Mr. William Richardson, Mr. William Frederick Palmer, and Mr. Edmund Hartley, the style of the firm becoming Platt Bros. & Co., the late Mr. E. Spencer joining the partnership in 1864.

In 1868 the business was transformed into a Limited Liability Company, Mr. Richardson becoming Vice-Chairman, and having the proud satisfaction of seeing his elder son George taking his place as a Director at the same Board as himself. Mr. Richardson continued to hold the position of Vice-Chairman to the time of his death. At the age of 29 he married Mary, the eldest daughter of Mr. John Gartside, Woollen Manufacturer, Cherry Clough, Saddleworth, His death took place at his residence, Werneth, Oldham, on the 16th December, 1892, at the age of 81.

Mr. Richardson joined the Association in 1873 as a Life Honorary Member, and up to recent years he rarely failed to attend at the Anniversary Meetings, and frequently on such occasions to make an acceptable donation to the Superannuation Fund.

James Taylor was a partner in the firm of Messrs. Buckley & Taylor, Castle Iron Works, of Oldham, and was born at Shaw, his father being Mr. Emanuel Taylor, of that Township. He was apprenticed as a fitter to Messrs. Wolstenholme & Rye, and he thus became acquainted with Mr. Samuel Buckley. In 1861 the two entered into partnership, and commenced the business of Engineers, which they have built up during the intervening 31 years into its present dimensions. Mr. Taylor was made a Borough Magistrate in 1891. He died on the 10th November, 1892, aged 54, leaving a widow and three children.

He was elected an Ordinary Member of the Association in the year 1878.

TREASURER'S GENERAL CASH ACCOUNT, FOR YEAR ENDING 31st DECEMBER, 1892.

Dr. *(Including Superannuation Fund Account.)* **Cr.**

1892.		£	s.	d.
Jan. 1.	To Balance as per last Report	3181	1	6
Dec. 31.	„ Contributions and Entrance Fees	488	16	6
	„ Transactions—sold	9	5	6
	„ Interest from Loans in Building Societies £23 0 0			
	„ „ „ Mortgages on Properties 90 9 6			
	„ „ „ Bank 2 5 2			
		115	14	8
		£3794	18	2

Audited and found correct,

T. DANIELS,
P. WARD,
I. SIMPSON,
} AUDITORS.

8th Sept., 1892.
9th Jan., 1893.

1892.		£	s.	d.
Jan. 1. to Dec. 31.	By Rent—Grand Hotel	20	0	0
	„ Secretary's Salary £80 0 0			
	„ Librarian's „ 7 10 0			
		87	10	0
	„ Superannuation Allowance	121	5	0
	„ Printing, Stationery and Bookbinding	180	9	9
	„ Books purchased for Library	4	5	4
	„ Insurance premium on Library	0	6	0
	„ Thirty-sixth Anniversary Dinner	11	15	0
	„ Audit and Committee Expenses, Postage and Petty Cash and expenses in connection with Social Meeting	71	2	10
	„ Expenses, *re* paper on "Manufacture of Iron"	8	0	0
	„ do. "Electric transmission"	8	6	0
	„ Advertisements: "City News"	1	6	0
	„ Funeral Allowances: Mr. G. Teale £10 0 0			
	„ E. Asquith 10 0 0			
	„ T. Cryer 10 0 0			
		30	0	0
	„ Cash Invested as Loans in Building Societies... 710 0 0			
	„ „ Advanced on Properties (Mortgages) 2400 0 0			
	„ „ in Bank 145 7 2			
	„ „ „ Treasurer's hands 27 7 7			
	„ „ „ Secretary's hands 22 17 6			
		3305	12	8
		£3794	18	2

SUPERANNUATION FUND ACCOUNT, FOR YEAR ENDING 31st DECEMBER, 1892.

Dr. *(Included in General Account.)* **Cr.**

1892.		£	s.	d.	£	s.	d.
Jan. 1.	To Capital invested as per Resolution passed at the Half-yearly Meeting, 14th June, 1879 ..	2100	0	0			
	„ Additional Capital voted at the Annual Meeting, 13th December, 1884	300	0	0			
	„ Additional Capital voted at the Annual Meeting, 12th Dec., 1891	600	0	0			
					3000	0	0
Dec. 31	„ Twelve Months' Interest on Capital Invested as per General Account				115	14	8
	„ Overdraft from General Account				5	10	4
					£3121	5	0

1892.		£	s.	d.	£	s.	d.
Jan 1. to Dec, 31.	By Superannuation Allowance..— Mr. Owen Williams	15	0	0			
	„ John R. Wolstenholme....	16	5	0			
	„ Richard Pearson.....	15	0	0			
	„ Fred Meixner	15	0	0			
	„ George Vickers	15	0	0			
	„ William Holmes.....	15	0	0			
	„ John Dutton	15	0	0			
	„ James Schofield	15	0	0			
					121	5	0
	„ Balance to credit of Superannuation Fund Account				3000	0	0
					£3121	5	0

Audited and found correct,

T. DANIELS,
P. WARD,
I. SIMPSON,
} AUDITORS.

9th January, 1893.